US Army Corps
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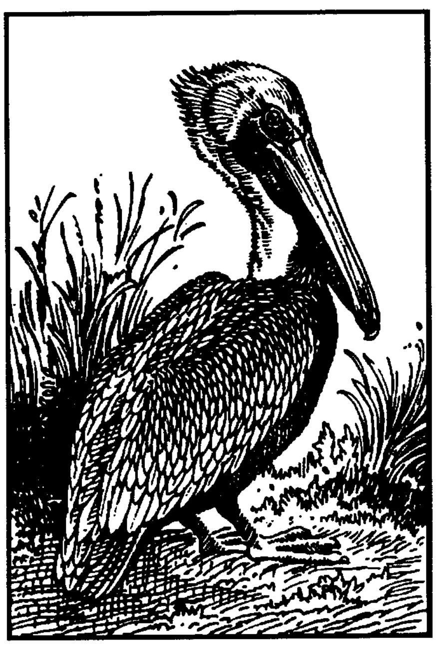
Wetlands Research Program Technical Report WRP-SM-7

Characteristics and Long-Term Sedimentation Patterns of Wetlands Constructed in the Fluctuation Zone of Grenada Lake, Mississippi

by Charles W. Downer, Ron DeLaune, J. Andy Nyman


August 1995 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

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Wetlands Research Program

Technical Report WRP-SM-7
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Characteristics and Long-Term Sedimentation Patterns of Wetlands Constructed in the Fluctuation Zone of Grenada Lake, Mississippi

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Final report

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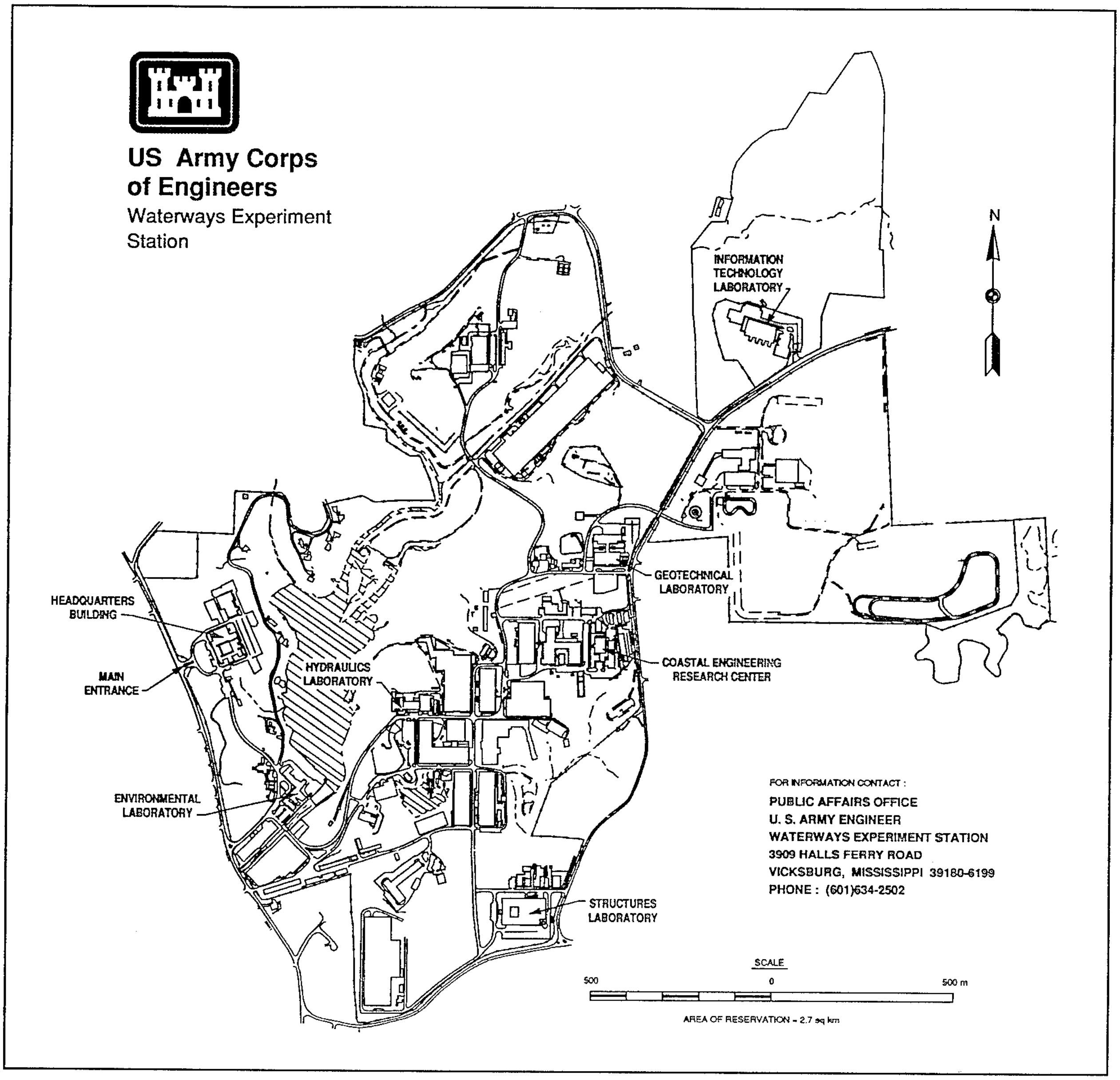

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Corps of Engineers Research Report Summary, August 1995

Sedimentation in Constructed Wetlands

Characteristics and Long-Term Sedimentation Patterns of Wetlands Constructed in the Fluctuation Zone of Grenada Lake, Mississippi (TR WRP-SM-7)

ISSUE:

The U.S. Army Corps of Engineers owns and operates hundreds of reservoirs for flood control and water supply. Operation of the reservoirs for flood control and water supply typically calls for a fairly predictable fluctuation of water levels within the reservoir. This operation provides lake managers with an opportunity to construct wetlands in the fluctuation zone of the reservoir, that area of the reservoir between flood and conservation pool. These wetlands potentially provide both habitat and water quality functions.

RESEARCH:

Wetlands constructed in the late 1950s within the Grenada Lake fluctuation zone were the focus of a study to document long-term sedimentation rates in constructed wetlands. These wetlands were originally constructed for waterfowl hunting and were planted with grains. Later abandoned, the "shooting ponds" became viable wetlands providing both waterfowl and fisheries habitat. Sediment cores from selected wetlands were collected and analyzed to determine the long-term sedimentation patterns in these wetlands.

SUMMARY:

Nine wetlands were located within the reservoir. Nineteen sediment cores from eight of these ponds were collected and analyzed for sediment accretion, bulk density, organic content, and particle size. Testing indicated the wetlands were accreting 0.5 cm/year of sediments. At this rate of infilling, the wetlands should remain as viable habitat for many more years. Though factors such as wetland position in the reservoir and drainage basin size are thought to influence sedimentation patterns in the wetlands, no significant differences in sediment accretion rates were observed between the wetlands in this study. Attempts to develop simple relationships between the sediment accretion data and physical characteristics of the wetlands were unsuccessful.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Author:

Mr. Charles W. Downer is a research hydraulic engineer at the U.S. Army Engineer Waterways Experiment Station Hydraulics Laboratory. Dr. Ron DeLaune is a professor at the Wetland Biogeochemistry Institute at Louisiana State University. Dr. J. Andy Nyman is a research associate at the University of Southwestern Louisiana. The point of contact is Mr. Downer at (601) 634-2473.

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Stewardship and Management Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32766, "Wetland Stewardship and Management Demonstration Areas," for which Mr. Chester O. Martin, Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), was the Technical Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work.

Mr. David Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitor's Representative; Dr. Russell F. Theriot, WES, was the Wetlands Program Manager. Mr. Martin was the Task Area Manager.

The work was performed under the direct supervision of Mr. Charles W. Downer, WES Hydraulics Laboratory (HL). Participants in this study included Dr. Ron DeLaune, Louisiana State University, and Dr. J. Andy Nyman, University of Southwestern Louisiana, who analyzed the sediment samples and prepared the report section on sediment sample analysis. Mr. Frank Schiebe of the U.S. Department of Agriculture National Agricultural Water Quality Laboratory in Durant, OK, provided for the analysis of preliminary sediment samples. Mr. Calvin Buie, HL, assisted in collection and sectioning of sediment samples. Dr. K. C. Jensen, EL, provided information on waterfowl habitat and served as a technical reviewer. Mr. David Scobey and the rest of the staff at the Grenada Lake Field office assisted in locating the wetland areas and obtaining information on the wetlands. Dr. Lisa Roig, HL, was the primary technical reviewer.

This report was written under the general direction of Mr. Glenn A. Pickering, Division Chief of the Hydraulic Structures Division and acting Branch Chief of the Reservoir Water Quality Branch, HL, Mr. Richard Sager, Assistant Director of HL, and Mr. Frank Herrmann, Director of HL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander of WES was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	0.40468564	hectares
acre-feet	1,233.48183838	cubic meters
cubic feet per second	0.02831685	cubic meters per second
Fahrenheit degrees	5/9	Celsius degrees[1]
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
square miles	2.58999776	square kilometers
tons (2,000 pounds, mass)	0.9071847	metric tons

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32).

1 Introduction

Grenada Lake is a U.S. Army Corps of Engineers (USACE) flood control reservoir located in northern Mississippi at the confluence of the Yalobusha and Skuna rivers (Figure 1). The reservoir was constructed in 1954 as part of the Yazoo Headwater Project flood control plan. During the late 1950s, the Mississippi Department of Wildlife, Fisheries and Parks constructed several small wetland areas on the expansive mudflats exposed during winter drawdown. Information on the original construction of these wetlands is scarce. However, it appears that these areas were developed by constructing low dikes across naturally low drainage areas and that the ponds were, and still are, shallow-water habitat. These wetlands were termed "shooting ponds" and were planted with grains to attract waterfowl for hunting. At the time the wetlands were constructed, the operating curve of the reservoir called for a lower summer pool. In 1967, the summer pool level was raised for recreation. After the change in the rule curve, the ponds were abandoned by the Mississippi Department of Wildlife, Fisheries and Parks. Many ponds remain and have become productive wetland habitat. The wetlands contain willows (*Salix* spp.), buttonbush (*Cephalanthus occidentalis*), and some emergent and submergent aquatic plants. During low-water years, the mudflats and wetlands become covered with various moist soil grasses and annual plants. These plants provide seed for waterfowl during the subsequent winter period.[1]

The old "shooting ponds" turned wetlands provided a unique opportunity to study the long-term sedimentation patterns of wetlands constructed within the fluctuation zone of reservoirs, that area of the reservoir between flood and conservation pool. Although sediment accretion has been studied in several types of wetlands, the information on sedimentation on wetlands within the fluctuation zone of reservoirs is scarce. Because constructing wetlands within the fluctuation zone of reservoirs is a new concept, studies on long-term sedimentation rates are practically nonexistent.

To determine the long-term sedimentation rates in the wetlands, several sediment cores were collected from eight of the wetlands located in the

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[1] Personal Communication, 1991, David Scobey, Park Ranger, Grenada Lake, Vicksburg District, USACE.

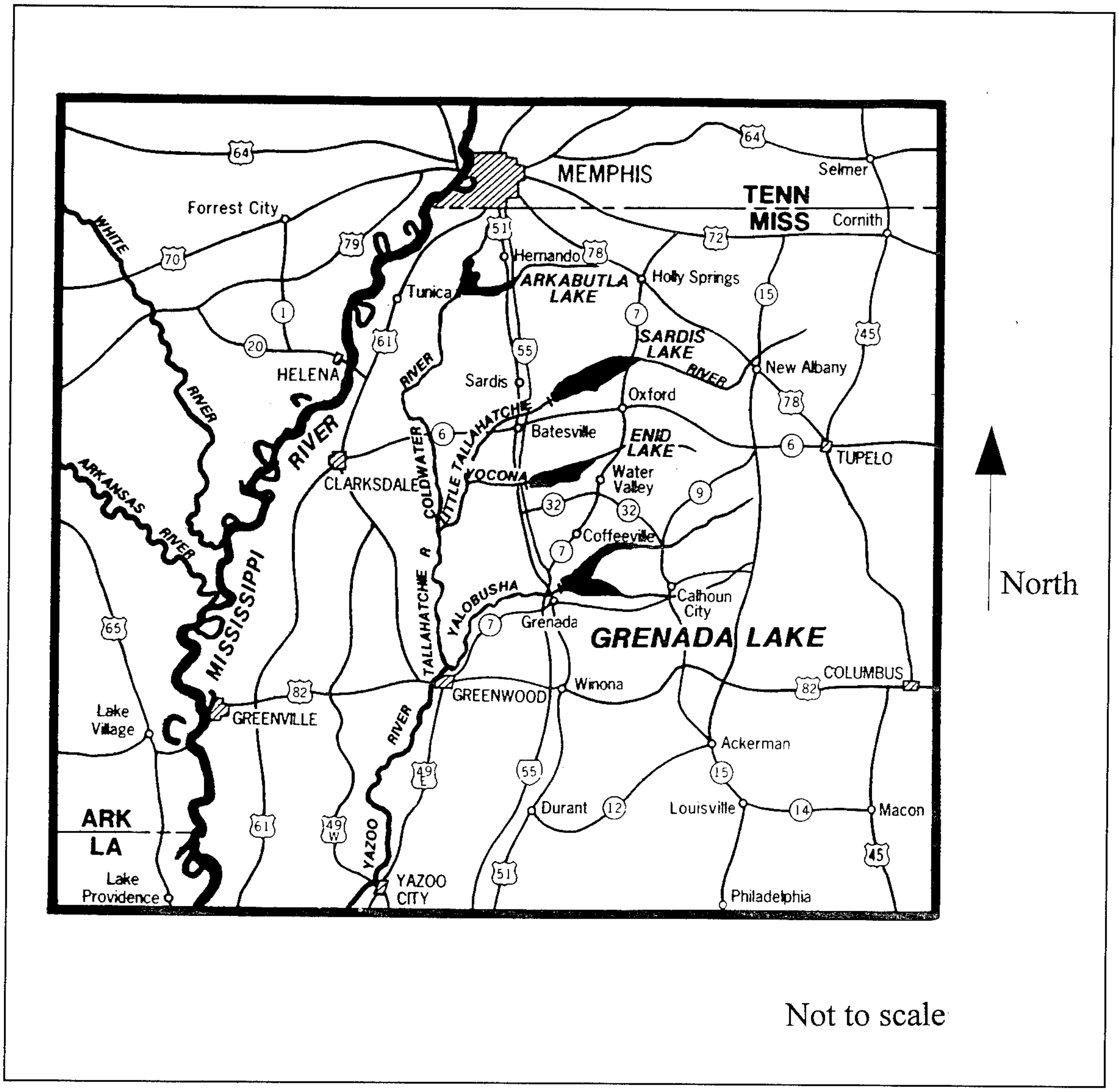

Figure 1. Grenada Lake

reservoir. These cores were then dated by ^{137}Cs at the Louisiana State University (LSU) Wetland Biogeochemistry Laboratory in Baton Rouge, LA. The bulk densities and organic content of the sediments were also determined. This information was used to determine long-term sedimentation rates in the wetlands and to infer additional information on the design of wetlands in reservoir fluctuation zones.

The purpose of this study was to document the characteristics and long-term sedimentation rates in constructed wetlands located in the Grenada Lake fluctuation zone. This information was then related to characteristics of the wetlands, such as elevation, location in the reservoir, and drainage area, to make recommendations on the construction of similar projects at other reservoirs. Such recommendations include sizing, construction techniques, and life expectancy.

2 Background Information

Pertinent data at the site consisted of areal maps of the project, daily records of reservoir stage, volume and outflows, and sediment surveys conducted in 1953, 1965, and 1978. Only the 1978 sediment resurvey documentation could be located (USACE 1979), although some information from the 1965 resurvey is contained in the 1978 resurvey. The Yalobusha River is gauged by the United States Geological Survey (USGS) at Calhoun City, roughly 20 miles[1] upstream of the reservoir. No other tributaries are gauged. No suspended sediment data for the reservoir or its tributaries were available.

Climate Conditions

Northern Mississippi is a semitropical region with high annual rainfall exceeding evaporation. Average rainfall in the area is around 55 to 60 in. (National Oceanic and Atmospheric Administration (NOAA) 1990), and evaporation from the lake is 41 in. per year (USACE 1979). Temperatures are moderate. Winters are cool and damp; and summers are hot and relatively dry, though precipitation is distributed throughout the year. Average winter temperatures are 40 to 60 °F. Low temperatures are rarely less than 20 °F. Average summertime temperatures are 70 to 80 °F, with highs nearing 100 °F.

Reservoir Operation

At elevation 231.0 ft National Geodetic Vertical Datum (NGVD), flood pool, the reservoir's surface area is approximately 64,000 acres. To create additional flood storage for spring storms, the reservoir is drawn down each winter to elevation 193.0 ft NGVD and occupies only 9,800 acres. Grenada Lake is refilled each spring during heavy storm runoff and is maintained at a summer recreational pool level of 215.0 ft NGVD. The operating, or rule, curve for the reservoir is shown in Figure 2.

[1] A table of factors for converting non–SI units of measurement to SI units is presented on page x.

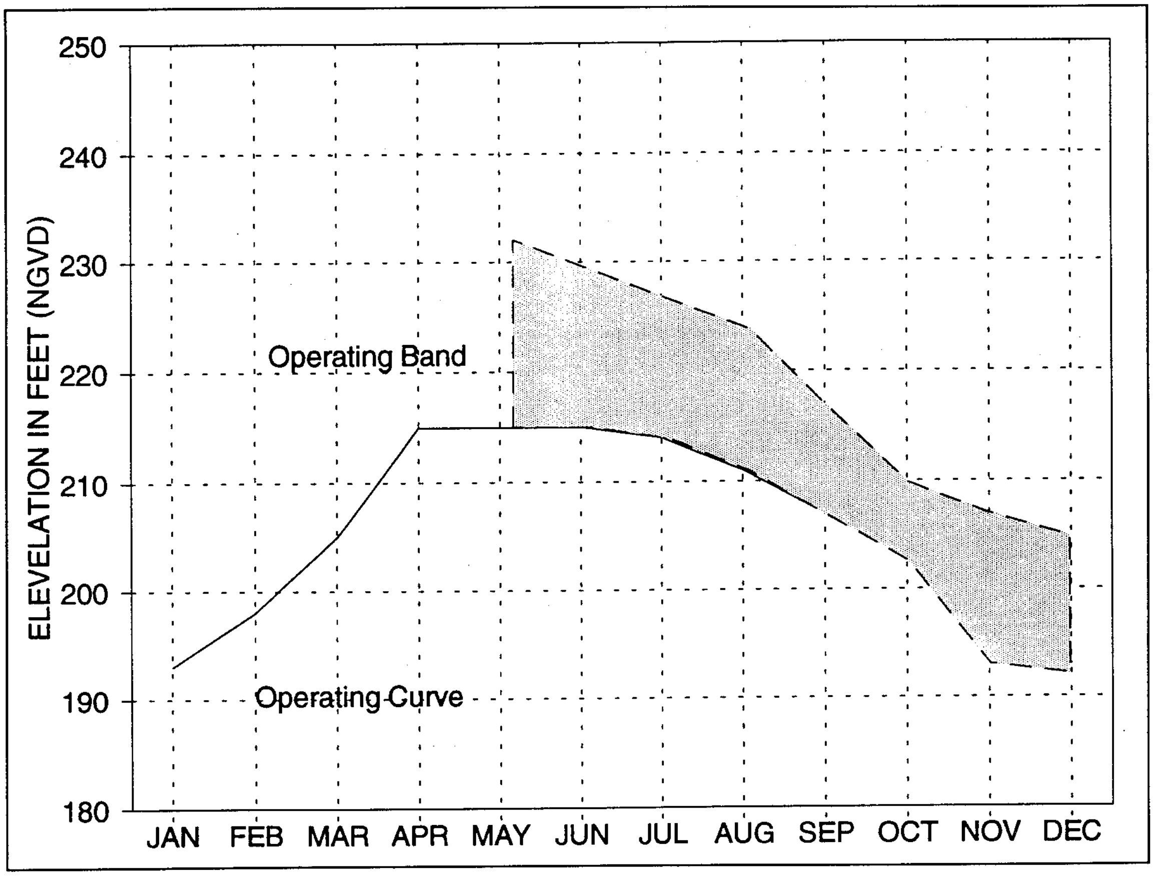

Figure 2. Grenada Lake rule curve

Reservoir Drainage Basin

Grenada Lake's watershed comprises a total drainage area of 1,320 square miles. The length of the basin is 45 miles, and the average width is 16.5 miles. The topography of the landscape is rolling hills with moderately narrow floodplains. Elevations within the basin vary from about 160 ft NGVD at the thalweg of the Yalobusha River up to 500 ft NGVD. The basin is mostly wooded with some acreage in agriculture and small towns that dot the area. Farming mainly occurs in the flat floodplains. Soils within the basin consist of poorly drained silty soils subject to flooding by the reservoir's backwaters, silty and clayey soils on the river floodplains, and sandy, clayey, and silty soils on the hilly uplands (from McMullen et al. 1965 and Thomas 1967).

Reservoir Flows

Outflows from the reservoir vary widely from year to year and even from day to day. The maximum controlled discharge from the reservoir was 7,700 cfs, recorded in 1983. Higher flows have passed over the emergency spillway. The average discharge from the reservoir since the beginning of operation has been 1,850 cfs. This equates into enough flow to displace the reservoir's volume every 1.5 years. Maximum monthly discharges from the reservoir are shown in Figure 3.

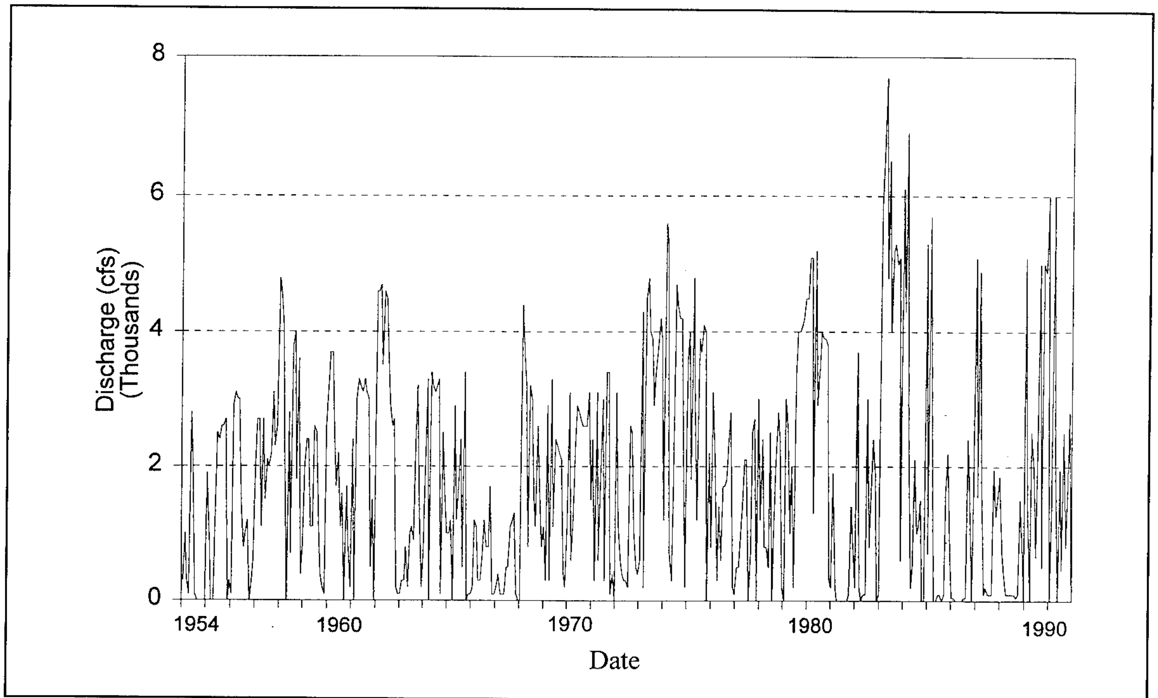

Figure 3. Grenada Lake historic discharges, January 1954 - January 1991

Reservoir Sedimentation

The sedimentation patterns in the reservoir are described by the 1978 sedimentation resurvey (USACE 1979). Sedimentation in reservoirs is determined by the USACE by establishing permanent sediment ranges. Each range contains several benchmarks. These benchmarks are periodically resurveyed, and the sediment accumulation in the lake is computed by the effective-length method.

The 1978 resurvey indicated that approximately 73,000 acre-ft of sediments had built up in the lake since 1953, equating to an overall accretion rate of 0.9 cm/year. The survey further indicated that the rate of sediment accumulation had increased substantially since the 1965 resurvey. Total accumulation from 1953 to 1965 was only 17,400 acre-ft, or 0.69 cm/year. Total accumulation from 1965 to 1978 was 55,400 acre-ft, or 1.04 cm/year. Based on sediment accumulation and flows, the average suspended sediment concentration of inflows is estimated at 1,511 mg/ℓ. The trap efficiency of the reservoir is thought to be very high (USACE 1979). Sediment accretion rates at different elevations are shown in Figure 4.

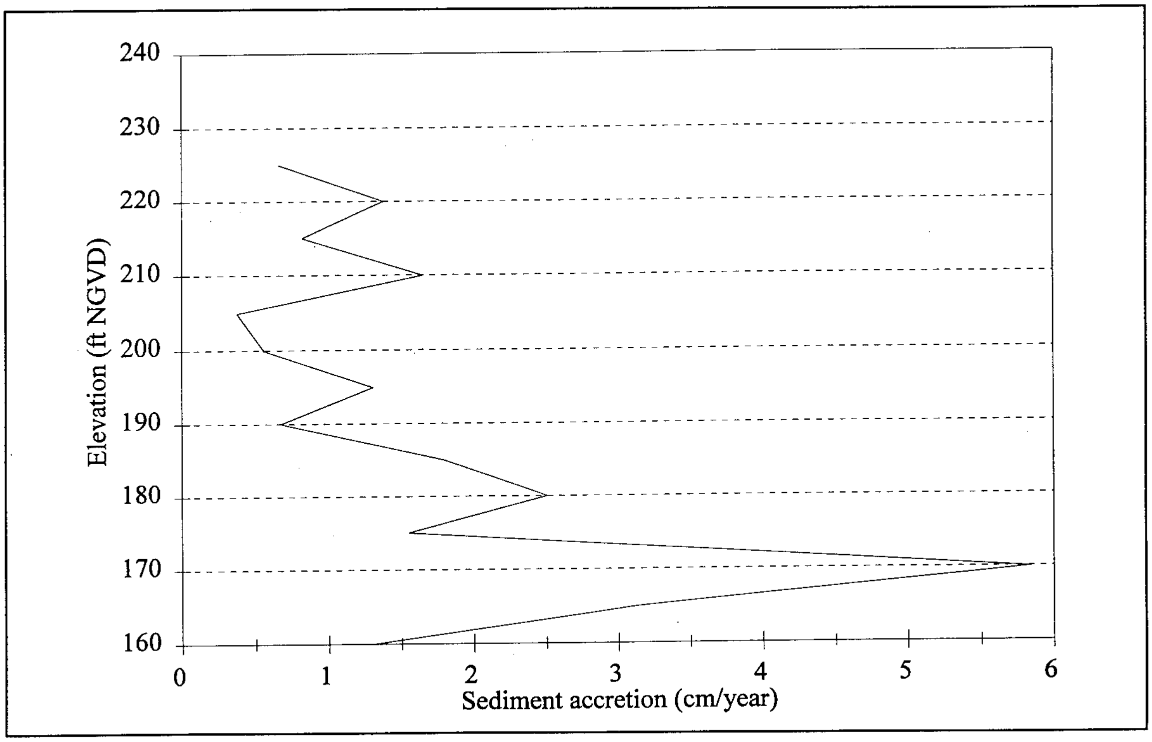

Figure 4. Vertical distribution of sediments in Grenada Lake

The greatest volume of sediment occurs in the 210- to 231-ft NGVD elevation range, which is essentially flood control storage. This is largely because most of the lake's area lies in this range of elevations. The sediment accretion rate in this range is not as high as other elevation ranges. As seen in Figure 4, the sediment accretion rate varies widely throughout the reservoir. The maximum sedimentation rate is in the 165- to 185-ft NGVD range, which would be some of the deepest areas near the dam. This information indicates that a large amount of the incoming sediments have very slow settling rates. These slow settling sediments are carried by the flow to the lower portion of the reservoir where they eventually settle. This is consistent with information from the soil surveys (McMullen et al. 1965; Thomas 1967) that indicate soils in the area are largely comprised of silts and clays. Soils eroding from areas at higher elevations within the reservoir are also accumulating in this region. The longitudinal distribution of sediment deposition is shown in Table 1.

Table 1 Longitudinal Distribution of Sediments in Grenada Lake										
% Reservoir Length	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
% Sediment	10.9	9.4	6.9	9.4	12.8	10.8	11.2	10.6	8.6	9.4

As shown in this table, the center of the reservoir is retaining the highest percentage of accumulated sediments, though sediments are distributed all along the length of the reservoir.

Description of Wetlands

The wetlands are found in the Butputter Creek Area, near the Yalobusha River and near the confluence of Skuna River and Turkey Creek. The locations of the wetlands are shown in Figure 5. Eight wetlands were selected for

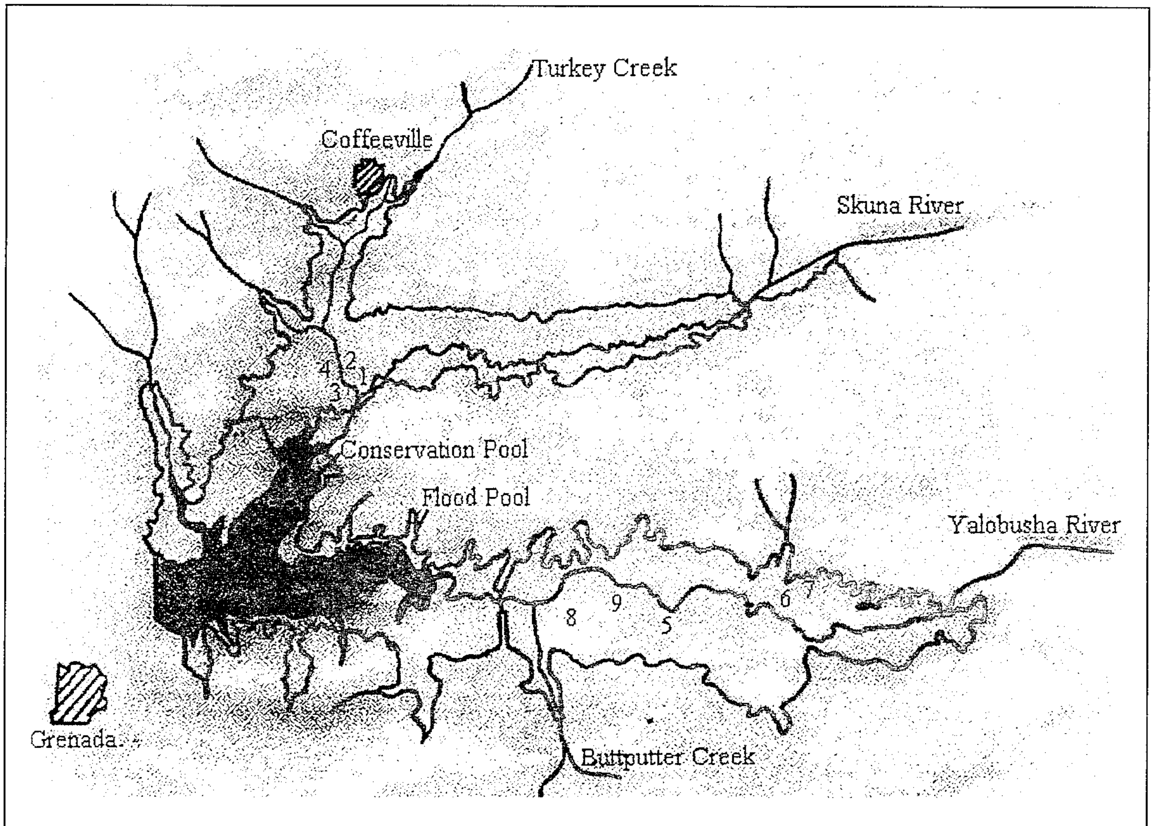

Figure 5. Wetland locations in reservoir

analysis. Wetland 4, also shown in the figure, was not sampled. It was completely filled with sediments at the time of sampling and contained no water. Physical data on each of the eight wetlands are presented in Table 2. Approximate elevations were taken from USGS topographical maps with 5-ft contour intervals. Wetland and drainage basin areas were estimated from USGS topographical maps, 1:24,000 scale, and from 1986 USACE areal photographs, scale 1 in. = 660 ft.

Table 2
Wetland Characteristics

Wetland Number	Location	Area acres	Drainage Area acres	Elevation ft NGVD
1	Skuna River/Turkey Creek	1.9	6.1	214
2	Skuna River/Turkey Creek	2.2	8.6	215
3	Skuna River/Turkey Creek	0.82	10.4	210
5	Yalobusha River	2.2	48	220
6	Yalobusha River	1.4	29	224
7	Yalobusha River	3.2	19.6	224
8	Yalobusha River	31.3	133	215
9	Yalobusha River	1.5	8.4	217

Construction and general condition

The wetlands were constructed by building dikes across small drainage areas within the reservoir fluctuation zone. Dikes were on the order of 1 to 2 m in height. Each dike contained some type of gated outlet structure. These structures were no longer operable. Most of the structures were completely filled with sediments or had been filled by beavers. Small breeches in the dikes of the wetlands acted as overflow spillways. Once the water had eroded the dikes down to the natural lake bottom, the clay soils prevented further erosion. Dikes in Wetlands 8 and 9 had been reworked. Riprap spillways were constructed for these dikes. Outflows still breached the dikes and created overflows similar to the other ponds. Because of the buildup of sediments near the dikes, the wetlands still encompass much of their intended area.

Vegetation

Vegetation in the wetlands along the Skuna River consisted primarily of emergent aquatic vegetation. Some submergent vegetation was also present. The water in these wetlands was clear. Vegetation in wetlands near the

Yalobusha River consisted primarily of woody vegetation, buttonbush, and willows. The water in these wetlands during drawdown was more turbid than the water in wetlands located along the Skuna River near Turkey Creek. During summers with normal or high water, 1990, 1991, there was little or no vegetation around the wetlands on the mudflats. During summers with abnormally low water, 1992, the mudflats were covered with a variety of moist soil grasses and plants. Lush vegetation was observed in and around the wetlands during the 1993 field trip to collect samples.

Relation to reservoir sediment resurvey

The 1979 sediment survey indicates that erosion is occurring on the hill-sides in the area of the reservoir where Wetlands 1, 2, and 3 are located, elevations 205 ft NGVD and above. Sediment accumulation is occurring at lower elevations, with most of the sediment accumulated in the 195- to 205-ft NGVD range. Erosion in the 210- to 215-ft NGVD range (elevations of Wetlands 1, 2, and 3) has been approximately 0.6 cm/year.

In the area of the reservoir along the Yalobusha River where the remaining wetlands are located, sediment has been accumulating at all elevations. Sediment accretion in the area has been approximately 0.3 cm/year. Sediment accretion at the elevation of the wetlands, 210 to 225 ft NGVD, has been about 0.8 cm/year.

3 Methodologies

Sampling

Sediment samples were collected from the wetlands during two field trips, a preliminary trip in March of 1992 and another trip in February 1993. During the 1992 field trip, two samples were collected from both Wetlands 6 and 8. Each sample consisted of eight cores, 10 cm in diameter. Each core was cut into 10-cm lengths, and the corresponding lengths from each of the eight cores were combined to obtain the mass needed for analysis, 1 kg. The combined cores were analyzed for ^{137}Cs courtesy of the United States Department of Agriculture (USDA) Sedimentation Laboratory in Durant, OK. Samples from the preliminary trip were used to determine the feasibility of the project and to refine sampling equipment and techniques.

After adjusting the sampling techniques, 19 samples were collected from eight wetlands during the 1993 field trip. The final equipment and methodology developed for obtaining samples are discussed in Downer (1993). Ten-centimeter-diameter cores were collected. Sample sites were reached by either wading or from a small aluminum boat. Samples were hand carried from the wetlands to a truck and then transported back to the laboratory for sectioning. Very soft samples were sectioned in the field. Any core that had changed appreciably in length from collection to sectioning was discarded. Samples from the 1993 sampling trip were cut into 3-cm sections, bagged, and later analyzed at the Wetlands Biogeochemistry Laboratory at LSU. All analyses were done on single core samples. The sampling locations in the wetlands are shown in Appendix A.

Laboratory Analyses

Core increments were weighed wet and then oven-dried at 80 °C to remove nonstructural water; the dry weight was then measured. Soil samples were initially placed on tarred aluminum foil for determination of wet weight, oven-dryed, and reweighed, but considerable amounts of soil could not be removed from the bags because of their wet, clayey nature. Preliminary tests suggested that the sample bags could survive oven-drying. Thus, most soil samples (over 17 cores) were weighed, dried, and reweighed in the sample bags. These weights were corrected for the weight of the bag by subtracting the oven-dried weight of cleaned, dried bags. This procedure was superior to removing the samples from the bags for weighing and drying on tarred foil. The error resulting from variability among bag weights was less than the error resulting from incomplete removal of wet samples from the bags.

The amount of vertical accumulation occurring since 1964 was determined in each core. Dried soil samples were crushed with a mortar and pestle and placed in a Marinelli beaker for determination of radioactivity. The gamma ray emissions from each sample were then counted with a 3- by 3-in. lithium-drifted Germanium detector and multichannel analyzer system (detector: Ortec model GEM-13190-S; multichannel analyzer: Canberra model 3502). Preliminary tests showed that 90 min of counting was sufficient to resolve ^{137}Cs activity above background noise (661.7 KeV). ^{137}Cs decays counted during the 90-min counting time were recorded for each core increment.

^{137}Cs does not occur naturally but is a product of nuclear fission (Walker, Parrington, and Feiner 1989). Maximum ^{137}Cs fallout occurred in 1963 when the United States and Russia conducted extensive atmospheric testing of nuclear weapons. Much of this fallout was subsequently washed into receiving basins worldwide in 1964; thus the 1964 surface is marked by the greatest ^{137}Cs activity. The depth of sediments that accumulated in each core since 1964 can therefore be determined from the depth of the ^{137}Cs maxima (Ritchie and McHenry 1990). Such vertical accretion is generally reported on an annual basis based on the depth of the 1964 surface and the number of years between 1964 and core collection (centimeters/year). The ^{137}Cs method is a nondestructive technique that is commonly used to determine vertical accretion in lakes (Ritchie and McHenry 1990) and marsh sediments (DeLaune, Patrick, and Buresh 1978). USACE personnel familiar with the projects report that the wetlands sampled in this study were constructed before 1964. If any wetlands were constructed afterwards, the vertical accretion rate (centimeters/year) estimated from the depth of the 1964 surface would underestimate actual vertical accretion.

The depth of sediments accumulating in the wetlands is only one parameter of interest. The mass of sediments that accumulate per unit area of wetlands (kilograms/square meter/year) is also a useful parameter for examining the role of wetlands in sediment trapping because sediment load data are generally reported on a mass basis. Calculating this mass per unit area requires knowledge of the bulk density and mineral matter content of the sediments. Thus, the percent mineral and percent organic matter of the accumulating sediments were determined after ^{137}Cs counting. Percent mineral matter content was determined on subsamples removed from the 3- to 6-, 9- to 12-, 15- to 18-, and 21- to 24-cm increments. These subsamples were combusted at 420 °C to remove organic matter (Ball 1964; Davies 1974).

Each segment of the remaining sample from each core was ground and mixed to form one sample per core. A grain-size analysis was performed on each of these samples. A standard set of sieves were used to determine grain size. The weight of the material, expressed as a percent of the total sample weight, that was retained on the size is recorded as percent coarser. Sediments passing through a number 200 sieve (0.075-mm opening) were classified as fines. Fines are comprised of silt and clay.

Calculations

Percent moisture was calculated from the wet and dry weights of core increments. Soil bulk density was calculated from the dry weight of each increment and the volume of the increments ($V = \pi r^2 h$; where $r = 5$ cm and $h = 3$ cm). Percent mineral matter was calculated from the preburn and postburn weight of subsamples. As noted, soil bulk density and percent mineral matter must be known to calculate sediment accumulation on a mass per unit basis.

Soil bulk density and percent mineral matter varied little; thus data from the 3- to 6-, 9- to 12-, 15- to 18-, and 18- to 24-cm increments were averaged to estimate average soil bulk density and percent mineral matter. Sediment accumulation since 1964 in each core was calculated from these parameters and vertical accretion with the following relationship:

Sediment accumulation (kg m^{-2} $year^{-1}$) = soil bulk density (g/cm^3) * percent soil mineral matter * vertical accretion (cm/year) * 10,000 cm^2/m^2 * 1 kg/1,000 g

Average sediment accumulation rates provide an estimate of the sediment accumulation rates that can be expected in the wetlands. In addition to determining average vertical accretion and sedimentation rates, factors affecting sediment accumulation were identified. Vertical accretion, average percent mineral content, average percent water content, average soil bulk density, and mass of sediments in each core were compared among impoundments with the Kruskal-Wallis test (Siegel and Castellan 1988:206-216). This statistical test was chosen for these analyses because it is not dependent on a normal distribution of data and because normality is difficult to demonstrate in small data sets. The Kruskal-Wallis test is the nonparametric equivalent to a one-way analysis of variance (ANOVA). This statistic tests the hypothesis that the samples come from the same population or from an identical population with the same median. Significant X^2 (Chi square) values would show that at least one pond differed from the others in the tested variable; i.e., vertical accretion, mineral content, water content, bulk density, or mass of sediments. Significant differences were defined as a probability less than 5 percent of obtaining a larger X^2 than actually obtained; i.e., significance indicated by $P < 0.05$.

Percent moisture and soil bulk density with depth in each core were tested for correlations using Pearson Correlation Coefficients (Steele and Torrie 1980). These tests were used to determine if sediments were changing over time, either through changes in the sediments being deposited or changes in the sediments after they were buried. Significant R values indicate that two variables change predictably with one another, with the degree of predictability indicated by the magnitude of R.

SAS[1] and JMP[2] Software were used to make the statistical tests and compute summary statistics. Standard statistical notation, i.e., the value of the test statistic, the degrees of freedom or sample size associated with that statistic, and the probability of obtaining a more extreme value, is provided for all statements supported by statistical tests.

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1 SAS Software Copyright 1987 by SAS Institute Inc., Cary, NC.
2 JMP Software Copyright 1991 by SAS Institute Inc., Cary, NC.

4 Results and Discussion

Preliminary Sampling Results

^{137}Cs profiles from the four preliminary samples are shown in Figure 6. The ^{137}Cs peak occurs within the top 10 cm of cores from Wetland 6 and within the top 20 cm of cores from Wetland 8. However, the 1963 peak was blurred within the top layers of the samples. At the time of analysis, the cause of the blurring was unknown. Frank Schiebe of the USDA soils laboratory in Norman, OK, stated that this kind of result is common in wetland samples and that bioturbation is the apparent cause.[1] Charlie Cooper from the USDA in Oxford, MS, thought that the ambiguous samples were probably the result of wind-induced mixing.[2] The wetlands are on large exposed mudflats with a large fetch in shallow water. It is also possible that the combining of several cores into one sample caused the blurring of results. The 10-cm sections may be too large to accurately define the 1964 peak in this case.

Although the information from these samples was useful for determining future sampling plans, it was not adequate to make meaningful determinations of long-term sediment accretion rates in the wetlands. To obtain more accurate results, it was determined that the ^{137}Cs analysis would be conducted on individual cores. These cores would be cut into shorter sections, 3 cm, for analysis. It was believed that this approach would solve the blurring problems observed in the original analysis.

1993 Sampling Results

With the modifications in both sampling equipment and techniques and analytical techniques, the ^{137}Cs peaks of each core collected during the 1993 sampling period were easily identifiable. The exception was Sample 1 from Wetland 5 where the sample appeared too short to contain the peak. The core collected from Wetland 5, site 1 had a ^{137}Cs maximum at the very bottom of

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1 Personal Communication, 1992, Frank Schiebe, USDA Soils Laboratory, Durant, OK.

2 Personal Communication, 1992, Charlie Cooper, USDA Sedimentation Laboratory, Oxford, MS.

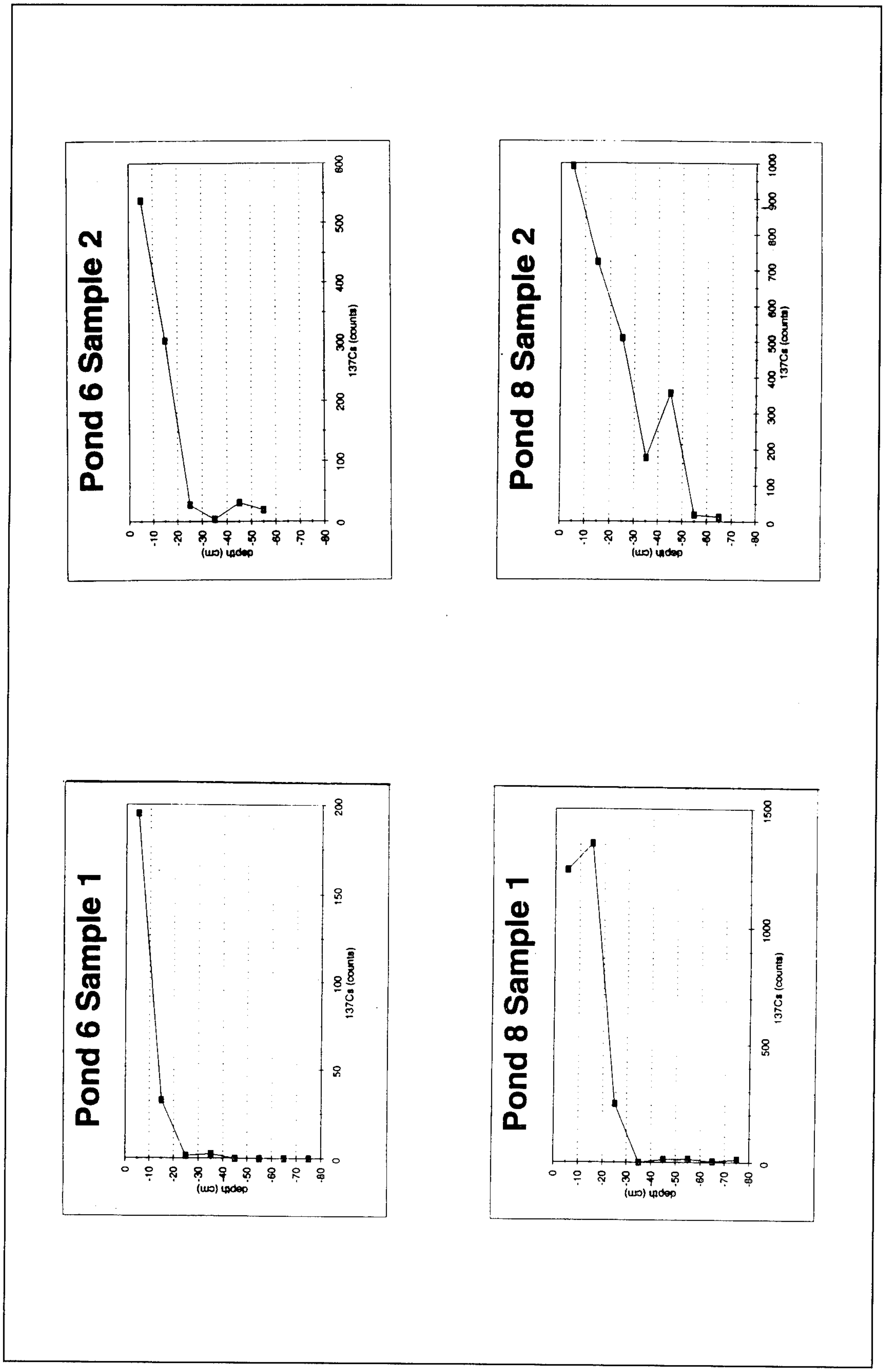

Figure 6. ^{137}Cs profiles of preliminary samples

the core. It is possible that the 1964 surface was at the very bottom of the core; but it is also possible that the 1964 surface lay several centimeters below that depth. Minimum vertical accretion and minimum sediment accumulation were estimated for this core, but those estimates were not included in the averages because of their uncertainty.

Vertical accretion varied almost 10-fold among the remaining 8 cores (Table 5). Analysis indicated no differences among the impoundments, although the difference was almost significant at the 95-percent confidence level (X^2 = 13.3404, 7 df, P = 0.0642). Results of sampling are shown in Table 3. Average values from the wetlands are shown in Table 4. Profiles from the cores are shown in Appendix B.

Table 3
Results of 1993 Sampling

Pond Number	Core Number	Location	Depth of 1964 Peak cm	Bulk Density g/cm³	Mineral Content % weight	Field Water Content % weight
1	1	inlet	7.5	1.17	95	26
	2	dike	10.5	1.25	96	29
2	1	dike	31.5	0.80	91	41
	2	inlet	16.5	0.99	94	35
3	1	dike	13.5	0.93	95	32
	2	inlet	16.5	0.83	92	35
5	1	dike	-	1.03	95	31
	2	inlet	13.5	1.04	93	29
6	1	inlet	10.5	1.25	96	24
	2	center	4.5	1.23	95	26
	3	dike	13.5	0.91	93	32
7	1	dike	13.5	1.15	93	26
	2	inlet	16.5	1.20	96	25
8	1	dike	4.5	1.04	96	25
	2	center	10.5	0.72	89	42
	3	inlet	4.5	0.84	92	33
9	1	dike	34.5	0.74	91	43
	2	center	16.5	0.62	91	44
	3	inlet	13.5	0.94	92	37

Sediment accumulation also varied greatly among the wetlands (Table 6). As with the vertical accretion rates, analyses indicated no consistent differences in sediment accumulation among the impoundments (X^2 = 12.1134, P = 0.0969).

Table 4
Average Values for Wetlands

Wetland Number	Vertical Accretion cm/year	Bulk Density g/cm^3	Mineral Content % weight	Sediment Accumulation $kg/m^2/year$	Field Water Content % weight
1	0.31	1.21	96	3.61	28
2	0.83	0.90	93	6.62	38
3	0.52	0.88	94	4.21	34
5	0.46	1.04	94	4.47	30
6	0.33	1.13	95	3.36	28
7	0.52	1.18	94	5.74	26
8	0.23	0.87	92	1.71	34
9	0.74	0.77	91	5.06	41
Average	0.49	1.00	94	4.35	32
Standard Deviation	0.21	0.16	2	1.52	5

The results of the grain-size analysis are shown in Table 5. Sediments from all cores from every pond had greater than 94-percent fine materials by weight. The average percent fines from all the cores was 98.2. The average percent sand was 1.4. There were no gravels or larger sizes. Wetland 9 had the largest percentage of fines by weight, 99.0. Wetland 6 had the least, 97.0. Complete data on grain-size analysis are provided in Appendix D.

Discussion of Results

^{137}Cs

Annual sediment accretion and mass accumulations between the wetlands varied widely, from a low of 0.23 cm/year in Wetland 8 to a high of 0.83 cm/year in Wetland 2. Had the additional measurement in Wetland 5 been included in the averages, then Wetland 5 would also have had an accretion rate of 0.83 cm/year. The average value was 0.49, and the standard deviation was 0.19 (Table 6).

The average sediment accretion in the wetlands was less than the overall sediment accretion rate in the reservoir. The mean reservoir accretion rate since 1954 has been approximately 0.9 cm/year, almost twice that of the mean wetland accretion rate. However, while Wetlands 1, 2, and 3, located near the confluence of Turkey Creek and the Skuna River, had accretion rates of 0.55 cm/year, erosion of the reservoir bottom in the same area is occurring at 0.6 cm/year. This indicates that the wetlands are retaining some percentage

Table 5
Grain-Size Analyses

Wetland Number	Sample Number	Percent Gravel by Weight	Percent Sand by Weight	Percent Fines by Weight	Average Wetland Percent Fines
1	1 2	0.0 0.0	1.8 1.0	98.2 99.0	98.6
2	1 2	0.0 0.0	0.7 1.0	99.3 99.0	99.2
3	1 2	0.0 0.0	0.2 0.3	99.8 99.7	99.8
5	1 2	0.0 0.0	3.3 2.3	96.7 97.7	97.2
6	1 2 3	0.0 0.0 0.0	5.7 1.9 1.4	94.3 98.1 98.6	97.0
7	1 2	0.0 0.0	1.4 4.2	98.6 95.8	97.2
8	1 2 3	0.0 0.0 0.0	3.5 0.9 1.7	96.5 99.1 98.3	98.0
9	1 2 3	0.0 0.0 0.0	0.7 0.7 2.1	99.3 99.3 97.9	99.0
Average		0.0	1.8	98.2	98.2
Standard Deviation		0.0	1.4	1.4	0.8

of the eroding lake bottom in the area. Soils eroded in the wetlands' drainage basins are later deposited in the wetlands and retained. This causes a buildup of sediments in the wetlands even though the wetlands occur in an erosional area.

For the wetlands located along the Yalobusha River, 5 through 9, the average accretion of sediments, 0.45 cm/year, is greater than the accretion of sediments in the general area, 0.3 cm/year, yet less than the accretion occurring at the same elevations in the general area, 0.8 cm/year. The accumulation of sediments in the entire region indicates that the reservoir is the source for sediments. While sediment deposition may be occurring equally inside and outside of the wetlands, sediments deposited in the wetlands may be scoured by high flows occurring during drawdown. These wetlands have substantial drainage basins that could produce high flows during the drawdown process or during storm events occurring at low pool levels. These flows may cause erosion, as opposed to deposition in the case of wetlands in the Turkey Creek area.

Table 6
Accumulation of Sediments in Wetlands

Wetland Number	Volume Accumulated m^3/year (acre-ft/year)	Mass Accumulated metric tons (tons)	Volume Accumulated Since 1964 10,000 m^3 (acre-ft)	Mass Accumulated Since 1964 metric tons (tons)
1	24 (0.019)	28 (31)	0.07 (0.56)	833 (917)
2	74 (0.060)	59 (65)	0.21 (1.74)	1,770 (1,950)
3	17 (0.014)	14 (15)	0.05 (0.41)	420 (460)
5	41 (0.033)	40 (44)	0.12 (0.96)	1,194 (1,320)
6	20 (0.017)	21 (23)	0.06 (0.48)	617 (680)
7	78 (0.063)	86 (95)	0.23 (1.83)	2,580 (2,840)
8	292 (0.236)	217 (239)	0.85 (6.85)	6,500 (7,160)
9	43 (0.034)	29 (32)	0.12 (1.00)	880 (970)
Sum	588 (0.48)	493 (543)	1.71 (13.82)	14,800 (16,300)

Bulk density and moisture content

Visual examination of the data suggested that percent moisture decreased with depth, and soil bulk density increased with depth. Pearsons Correlation Coefficients calculated using all bulk density and percent-moisture estimates from the surface to 36-cm depth indicated that bulk density and percent water were negatively correlated (R = -0.8724, N = 226, P = 0.0001), and that bulk density increased with depth, and percent water decreased with depth. Kruskal-Wallis tests indicated no differences among impoundments in bulk density (X^2 = 11.64963, 7 df, P = 0.1127) or water content (X^2 = 12.3595, 7 df, P = 0.0893). Soil bulk density averaged 0.98 g/cm^3 (N = 19, SE = 0.04). Moisture content averaged 32 percent (SD = 6); bulk density averaged 0.98 g/cm^3 (SD = 0.19). Bulk density and percent-water profiles from the cores are shown in Appendix C.

Organic matter

The sediments were low in organic matter content; average mineral matter content was 93.4 percent (SD = 2.1). Analyses indicated no differences among the impoundments in organic matter content (X^2 = 9.3786, 7 df, P = 0.2266).

Particle size

No statistical tests were run on the grain size. All samples were very high in percent fines. There were no apparent trends in these data. Wetlands 5, 6, and 7 had the greatest amounts of coarser materials. These three wetlands are located near Old Highway 8, which may provide a source of larger materials.

Distribution of sediments in wetlands

Sediment accumulation was greatest near the dikes of the wetlands in four out of eight cases. Sediment accumulation was slightly greater near the inlets of Wetlands 3 and 7. Sediment accumulation was greatest in the center of Wetland 8; and no comparison could be made in Wetland 5 where only one of the two samples yielded conclusive results. Particle size plays an important role in the distribution of sediments in wetlands. Small-size particles require more time to settle than larger particles. The sediments in the wetland are comprised of 98-percent silts and clays. These particles require a long time to settle and typically do not settle near the inlet as would sand or larger size particles. The long settling time of silts and clays causes them to stay in suspension longer. Many of these particles are carried by the flow to the lower end of the wetland where they eventually settle to the bottom. The distribution of sediments in the wetlands reflects the prevalence of small-size particles.

Accumulation of sediments

The estimates of accumulation for each wetland are shown in Table 6. As shown in the table, the wetlands have retained approximately 10,700 m^3 (14 acre-ft) of sediments since 1964. Most of the sediment is contained in Wetland 8, which has the largest surface area. Sediments deposited in the wetlands are retained in the flood-control area and prevented from moving into the conservation pool of the reservoir. While this helps to preserve the water depth and protect recreational use, it causes a loss of storage volume in the flood-control pool.

The amount of sediment contained in the wetlands is very small when compared with the total sediment accumulation in the reservoir, which is estimated at 73,000 acre-ft from 1953 to 1978 and is insignificant in relation to the total reservoir volume of over one million acre-feet.

Assuming an average wetland water depth of 0.5 m, at the current rate of filling, the wetlands will be completely filled in from 60 years for Wetland 2 to 220 years for Wetland 8. The rate of filling may be reduced as wetland volume is lost and retention times in the wetlands are shortened and sediment trapping efficiency is reduced. This could extend the useful life of the wetlands.

5 Reservoir and Wetland Influences on Sedimentation

Determining the accumulation of sediments in the wetlands was one purpose of this study. A second reason was to learn what factors can be used to predict sedimentation in fluctuation zone wetlands. Sedimentation in a wetland located within the fluctuation zone of the reservoir is affected by the source of sediment. The first source is the drainage basin of the wetland. This is the source of sediment when the wetland is not inundated by the lake during drawdown. The second source of sediments is the reservoir. This sediment is provided to the reservoir from the major tributaries. When the wetland is inundated, some of this load is deposited in the wetland. If the wetland is near a major tributary, then the tributary itself may become a third source of sediments. Tributaries may overflow their banks and spill into the wetland before the reservoir backs up into the wetland. In this case, the sediment load is directly deposited into the wetland and sediment accretion in the wetland can be high. Several factors affect sediment loadings and retention in the wetlands. Some of these factors may be useful for predicting sediment accumulation in fluctuation zone wetlands. These factors are discussed below.

Elevation and Flooding Frequency

Elevation of the wetland may influence sedimentation in several ways. Elevation influences how frequently the wetland is inundated. The elevation may also be related to the proximity of the wetland to a major channel. A hypothesis of this study was that wetlands that are more frequently inundated, at a lower elevation, would have higher sediment accretion because of increased loadings from the reservoir. The elevation may also affect vegetative species and density that affect flow properties in the wetlands.

The historical water surface elevations for Grenada Lake are shown in Figure 7. As shown in the figure, the reservoir is drawn down to 193 ft NGVD each winter. The maximum yearly water surface elevation depends on the amount of spring runoff. During very wet years such as 1984, the maximum reservoir elevation was 236.3 ft NGVD, exceeding the spillway

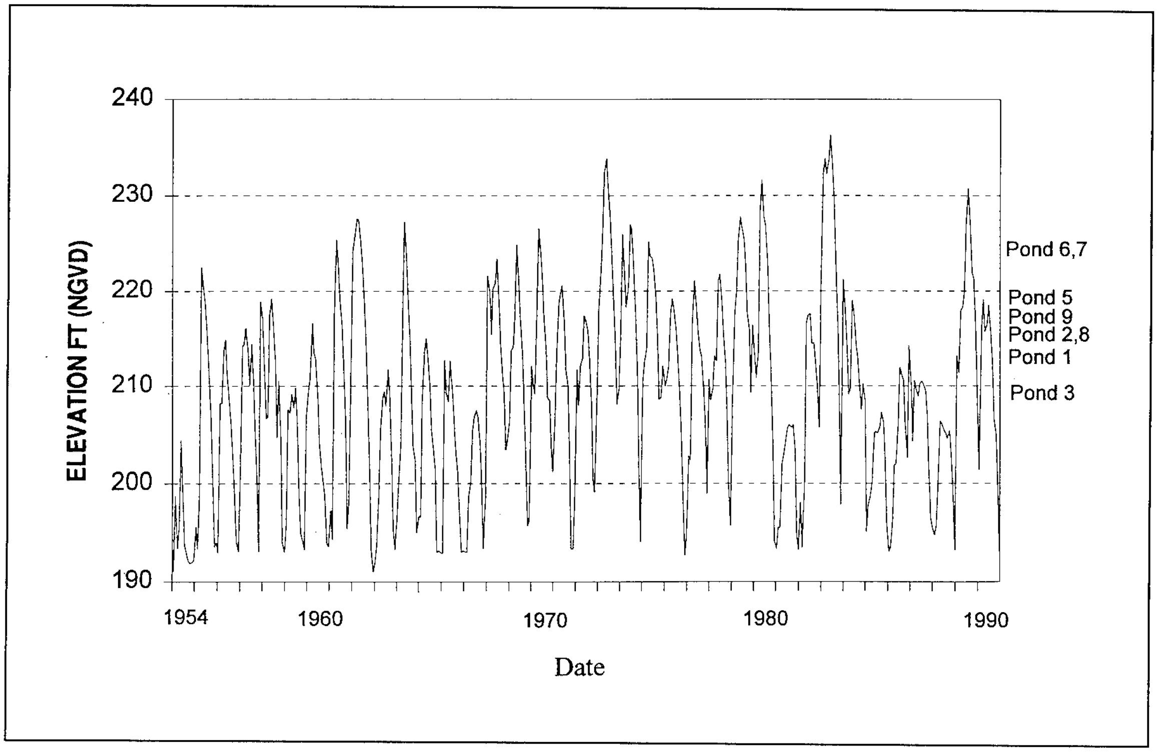

Figure 7. Grenada Lake historic water surface elevations, January 1954 - January 1991

elevation of 231 ft NGVD. During dry years such as 1987, the maximum water surface elevation may be around 200 ft NGVD. There is an apparent shift in the operation of the reservoir around 1970. This is because the rule curve of the reservoir was changed in 1967, going to higher summer elevations for recreation.

Elevations of each wetland are shown in Figure 7. Based on their elevation, the flooding frequency of the wetlands can be quite different. An analysis was conducted to determine the amount of time that each wetland would be inundated. The results of this analysis are shown in Table 7. Values in the table indicate the percentage of time that the wetland has been inundated by the reservoir.

As shown in the Table 7, Wetlands 1, 2, and 3, located near the Skuna River and Turkey Creek, are at the lowest elevations and are the most frequently inundated. Wetlands 8 and 9, located furthest down the Yalobusha River, are inundated much more frequently than Wetlands 6 and 7, which are inundated less than 10 percent of the time. The flooding frequency of all the wetlands significantly increased after 1967 when the rule curve of the reservoir changed.

Table 7
Wetlands Flooding Frequency

Wetland Number	Flooding Frequency % of Time Inundated		
	1953-1990	1953-1967	1967-1990
1	32.5	18.9	41.0
2	30.0	16.5	38.0
3	47.7	31.4	58.0
5	18.1	9.2	23.7
6	8.5	3.8	11.4
7	8.5	3.8	11.4
8	24.1	12.0	31.7
9	29.7	16.5	38.5

Drainage Basin Size

The size of the drainage basin is considered important for two reasons. First, the size of the drainage basin affects the sediment load to the wetland. The size of the drainage basin also affects the amount of volume of runoff and peak flow to the wetland. Large drainage area increases runoff during storm events. High runoff results in higher sediment loads and could therefore be expected to increase sediment accumulation. However, high flows result in shorter detention times in the wetland, which can lower sediment retention rates. Drainage basin characteristics will be most important during draw-down, when the wetlands are not inundated by the reservoir.

Wetland Surface Area

The wetland size affects the detention time of the wetland. For a given drainage basin size, larger wetlands should retain more incoming sediments. The accumulation per unit area may or may not be higher because of increased wetland surface area.

Wetland Size/Drainage Basin Ratio

The size of the wetland in relation to the drainage basin size of the wetland is an indirect measure of hydraulic retention time (HRT), which is approximately equal to the wetland volume divided by the flow rate. Wetland volume is represented in the ratio by the wetland surface area. Flow rate is dependent upon and represented by the drainage basin size. While a wetland with a long retention time, high ratio, would be expected to retain a high percentage of the delivered suspended sediments, a wetland with a relatively large drainage basin, low ratio, would have increased sediment loading. Therefore, sediment accumulation could be expected to be high or low with either condition.

Wetlands' Position in Reservoir

The position of the wetland within the reservoir can be an important factor in sediment accumulation. One measure of position in the reservoir is the elevation, as discussed above. Another measure of the position in the reservoir is the longitudinal positioning. As shown in Table 2, sediment accumulation varies along the longitudinal axis of the reservoir, with the greatest percentage of sediments being accumulated in the center of the reservoir. The position of the wetland in the reservoir also affects the vegetative community in the wetland.

Flow Conditions

Flow conditions within the wetlands greatly affect sedimentation in the wetlands. Flow conditions in the wetlands are affected by wetland configuration, hydraulic structures, and vegetative species and densities. Hydraulic structures and vegetation provide flow resistance in the wetlands. The hydraulic structures are primarily responsible for flow control within the wetlands; vegetation provides additional flow resistance. The condition of the control structures and importance of vegetation in providing flow control has changed over the life of the projects. The vegetative community has also changed over the life of the project. The history of these changes are undocumented, so that no meaningful analyses of the effects of flow conditions or resistance on sedimentation could be made.

Discussion of Regression Analyses

One goal of this project was to develop generalized expressions that could be used to predict sedimentation in fluctuation zone wetlands. Because there is no measure of suspended sediment loads or flows into the wetlands, the equations would have to be developed from general characteristics of the wetlands. Measures of each of these factors and the corresponding sediment accumulation are shown in Table 8. The wetlands are listed according to their estimated annual sediment accumulation in descending order. Listing the wetlands in this manner should help to point out any apparent trends in the data. Linear regression analyses were conducted between the different factors and annual sediment accumulation and accretion.

Table 8
Factors Thought to Influence Sediment Accumulation in Wetlands

Wetland Number	Elevation ft NGVD	Frequency of Inundation % time	Surface Area (SA) acre-ft	Drainage Area (DA) acre-ft	Wetland SA/DA	Relative Longitudinal Position % reservoir length	Sediment Accumulation kg/m²/year
2	215	30	2.2	8.6	0.26	23	6.62
7	224	8.5	3.2	19.6	0.16	78	5.74
9	217	29.7	1.5	8.4	0.18	56	5.06
5	220	18.1	2.2	221	0.01	62	4.47
1	214	32.5	1.9	6.1	0.31	23	4.21
3	210	47.7	0.8	10.4	0.08	23	4.21
6	224	8.5	1.4	29	0.05	78	3.36
8	215	24.1	31.3	133	0.24	52	1.71

Although these and other factors are known to play a role in the sediment accumulation in the wetlands, attempts to derive simple relationships, through linear regression analyses, between the observed sediment accretion/mass accumulation and the factors listed in Table 8 were unsuccessful. Regression analysis yielded low-correlation coefficients and poor visual fits, indicating that simple relationships among the chosen variable did not exist or were very weak. Simple observation of Table 8 indicates no obvious trends between sediment accumulation and the listed variables.

The low number of samples available may have hindered the analyses. Eight samples do not provide enough data to draw conclusions unless the trend is very strong. Statistical tests of the accumulation rates indicated that there was no difference between the wetlands. Therefore, it is no surprise that there are no trends in data to come from the same set.

Differences in drainage basins, proximity to tributaries, effects of other wetlands, and other factors may play a large role in the sedimentation process. For example, Wetlands 6 and 9 are both located downstream of other constructed wetlands. Wetland 6 is located downstream of Wetland 7. Wetland 9 is located downstream of another unsampled wetland. The upstream wetlands may remove most of the incoming sediments from flows during low-water conditions. This is probably important in Wetlands 6 and 7, which are infrequently inundated by the reservoir. While Wetland 7 intercepts water from almost the entire drainage area for Wetland 6, Wetland 9 has significant drainage area that is not intercepted by the upstream wetland. Sediment accretion in Wetland 9 is much higher than Wetland 6. This may partially explain the differences in sedimentation rates in the two wetlands.

Wetlands 1, 2, and 3 are all located near the confluence of the Skuna River and Turkey Creek. However, Wetlands 1 and 2 are much closer to Turkey Creek than Wetland 3, with Wetland 1 being the closest. Overflows from Turkey Creek may dominate the sedimentation in the area, and the closer the wetland to Turkey Creek, the higher the sedimentation rate. Sediment accretion differences could also be caused by erosional differences between the small drainage basins of the wetlands because of differences in vegetation and soil characteristics.

While the above discussion is not meant to explain the variations in sediment accumulation among the wetlands, it does point out several complicating factors in estimating sediment accretion in a wetland located within a reservoir. This study indicates that simplistic methods to determine sedimentation rates are infeasible. Interrelationships among these and other complicating variables, such as elevation, frequency of inundation, and vegetative community, prohibit the use of any one possible factor as a reliable indicator for sedimentation rates. Selection of sites and design should be based on the analysis of individual site conditions with both large-scale, reservoirwide and small-scale, wetland drainage basinwide factors being considered. While one or the other scale factors may be insignificant, this should be decided on a case-by-case basis.

6 Conclusions and Design Recommendations

The development of wetlands has been shown to be a useful long-term, inexpensive measure for providing wildlife and fisheries habitats and sediment retention. Because of the uncertainties between the relationships between reservoir and wetland characteristics and sedimentation in the wetlands, no strict design criteria can be listed. However, the study showed several points that should be considered in the analysis or construction of similar projects.

Sediment Analysis

Sediment accretion in the wetlands is on the same order of magnitude as sediment accretion in the reservoir. Average wetland sediment accretion is about half of that measured in the reservoir. Assuming that the wetlands will accumulate sediments at approximately the same rate as the reservoir is likely a good starting point for screening level analysis. Using the observed sediment accretion rate in the area that the wetlands are to be located may provide a better estimate if the area is accreting and not eroding. If the area is eroding, then the wetlands can be anticipated to accumulate some amount of this eroded material. Estimating this amount would require a more detailed analysis.

Microgeographic differences within the reservoir and the wetlands are thought to play a large role in the sediment accumulation in the wetlands. Finding general relationships between sediment accumulation and factors such as elevation, flooding frequency, surface area, drainage area, and position in the reservoir was not possible. It is thought that these small-scale differences play a large role in the sedimentation patterns in the wetlands.

Although simple mathematical relationships between wetland characteristics and sediment accumulation could not be defined, the characteristics in Table 8 are still thought to be important for sedimentation analysis. The interrelationship among the variables may have blurred the effects of any one element. Important factors to consider in locating wetlands in the fluctuation zone of reservoirs are elevation and frequency of inundation, longitudinal position in the reservoir, proximity to tributaries, size, drainage-basin size and characteristics, and vegetative species and density. The relative effect of any of these factors will be lake and wetland dependent. For wetlands that are infrequently inundated, wetland and drainage-basin characteristics are thought to be more important. For wetlands that are frequently inundated, position in the reservoir plays an increased role.

Wetlands located within the fluctuation zones of reservoirs have the effect of retaining sediments in the flood-control pool and preventing them from reaching the conservation pool. While this protects recreational use of the reservoir, it displaces some flood-control volume. Small wetlands located in large reservoirs have very little effect on the total sedimentation patterns. However, if large areas of wetlands are constructed in small reservoirs, the effects could be significant.

The useful life of the wetlands for habitat and sediment accumulation is estimated to be between 60 and 220 years, assuming a pre-1964 construction date. This long life span is predicted despite a very high sediment loading to the reservoir, average inflow concentration of 1,500 mg/ℓ. This would suggest a large return on a small initial investment and makes the wetlands an attractive habitat and water quality investment.

Design Recommendations

Wetlands located within the fluctuation zone of reservoirs are subjected to frequent inundation, strong wave action, and modification by beavers and other animals. Construction techniques and control structures should be kept simple and low cost. Wetlands should be located where the topography allows for creating a small basin with minimal earthwork. Earthen dikes should be constructed where adequate dike material is available onsite. Using onsite materials preserves flood control volume and contains cost. In general, gated or movable control structures should be avoided because they will quickly become inoperable. A simple earthen, rock, or concrete spillway or weir is the best outlet structure. When providing wildlife habitat is the main function of the wetland, the ability to manipulate water levels within the wetland becomes necessary. Precise water control (within 5 cm) is needed to encourage the growth of vegetative species that are highly desirable for wildlife, such as sedges, smartweeds, and annuals.[1] The most practical way to provide this level of water level fluctuation in wetlands constructed within a flood control reservoir is to install a stoplog structure. Stoplog structures are drop structures or overflow weirs with a crest height adjusted by adding or removing sections made from wood, steel, or polyvinyl chloride (PVC). Watkins (1992) describes the design, construction, and application of PVC stoplog structures.

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[1] Personal Communication, 1994, K. C. Jensen, Ecologist, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Selection of an appropriate site should be based on the desired functions of the wetland. If the wetland is to be used for sediment control and water quality improvement, the wetland should be located in an area where sediment loads are high. If the wetland is to be used primarily for habitat purposes, then the location, particularly the elevation, plays an important role in how useful the wetland will be to certain species. An analysis similar to one described in this document should be conducted to learn the frequency and duration of inundation of potential wetland sites. This frequency and duration of flooding, often called a hydroperiod, will in large determine which plant species will grow at the desired location. If specific plant species are needed, then the flooding tolerances of these plants should dictate the selection of the site.

Habitat Implications

Wetlands located within the reservoir fluctuation zone provide habitat for a variety of mammals, birds, reptiles, amphibians, and fishes. Beavers are prevalent in these wetlands and often make changes to the wetlands, such as filling control structures and even raising dike levels. Other mammals use the wetlands as a source of water during drawdown. Waterfowl frequent the wetlands during drawdown and provide opportunities for hunting. Reservoirs generally provide poor habitat for wintering waterfowl because of poor food availability (Johnson and Montalbano 1989). However, if properly managed, fluctuation zone wetlands can increase the habitat quality for wintering waterfowl. The larger wetlands also retain water year-round and are popular fishing areas in the lake during winter drawdown.

The use of the wetlands by different species is dependent upon the operation of the reservoir. During years with low water in summer, the mudflats become overgrown with vegetation, and a variety of mammals move into the lake bed and use the wetlands. The seeds and tubers from the vegetation also provide food for migrating and wintering waterfowl. During high-water years, the mudflats are typically barren and support fewer plant and animal species. Waterfowl still use the woody vegetated wetlands as rest areas, but they provide much less food value. There is little food available for herbivores, such as seed-eating birds, rabbits, and deer. Changes in the rule curve to allow for more low-water summer periods would increase the productivity of the wetlands. Waterfowl habitat is increased by spring/summer drawdowns followed by fall/winter flooding.[1]

Wetlands can also provide a variety of fish habitat, depending upon wetland size and location. Large, deep wetlands, located nearer the conservation pool level can hold water year-round and provide for fish habitat during winter drawdown. When wetlands are inundated by the lake, they provide

[1] Personal Communication, 1994, K. C. Jensen, Ecologist, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

structure for fishes, whatever their size or elevation. Wetlands at higher elevations may provide spawning areas during spring high-water levels.

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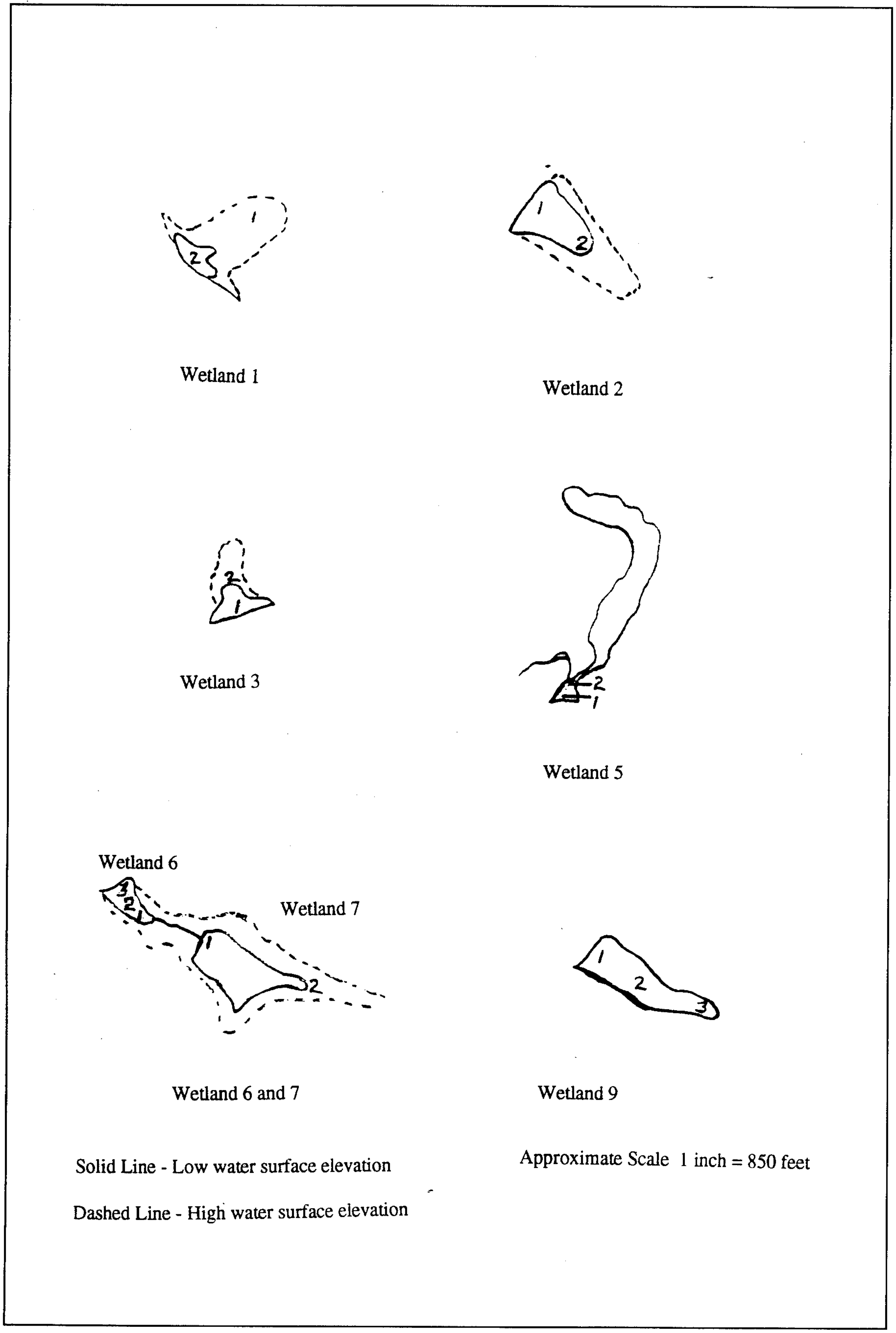
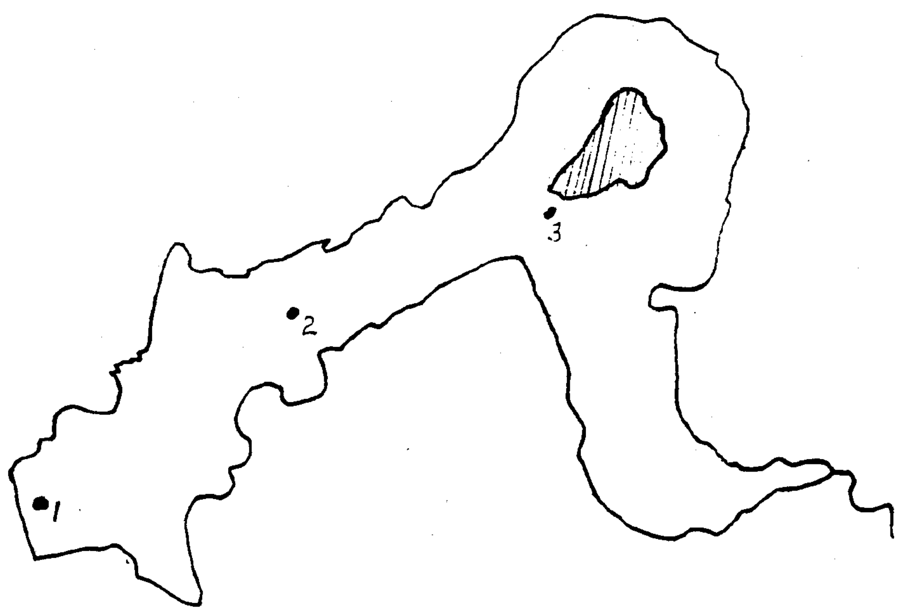
Appendix A
1993 Sampling Locations



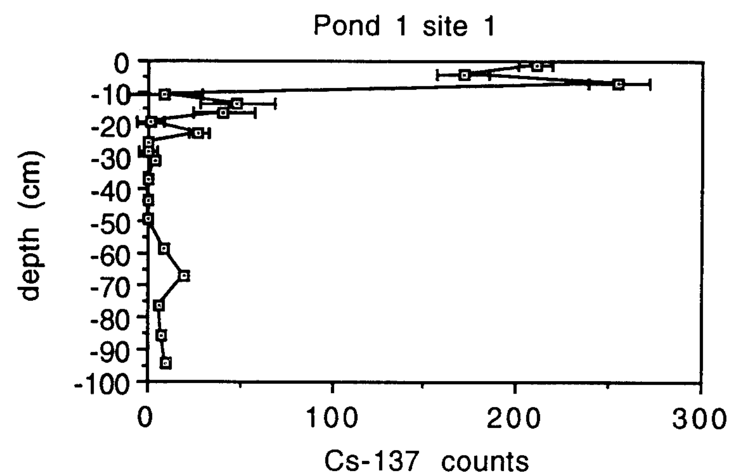
Wetland 1
Wetland 2
Wetland 3
Wetland 5
Wetland 6
Wetland 7
Wetland 6 and 7
Wetland 9
Solid Line - Low water surface elevation
Dashed Line - High water surface elevation
Approximate Scale 1 inch = 850 feet

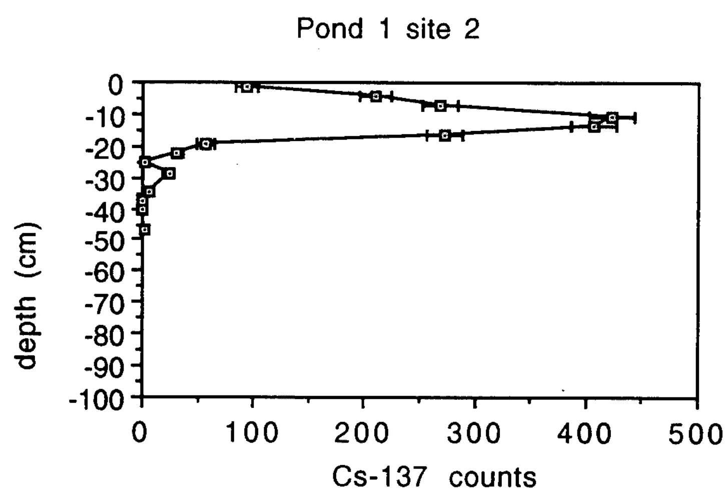


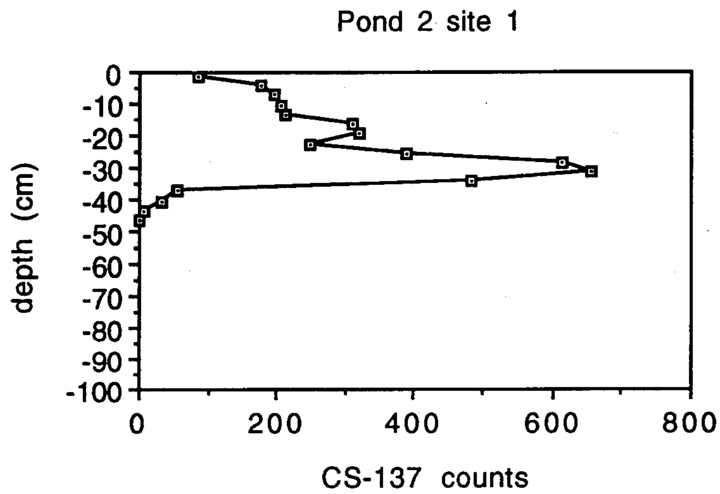
Wetland 8

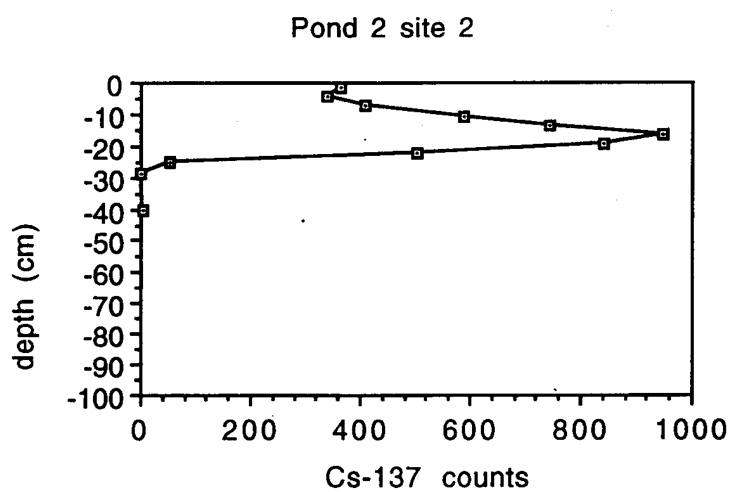
ApproximateScale 1inch = 850 feet

Appendix B
^{137}Cs Profiles from 1993 Samples

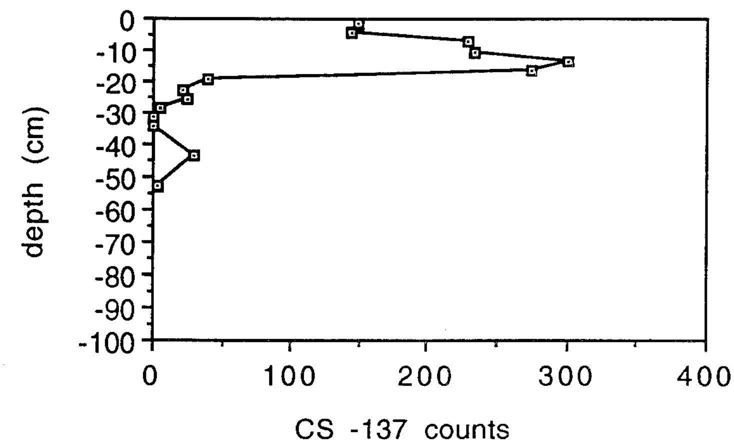

Pond 1 site 1
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
Cs-137 counts


Pond 1 site 2
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
500
Cs-137 counts

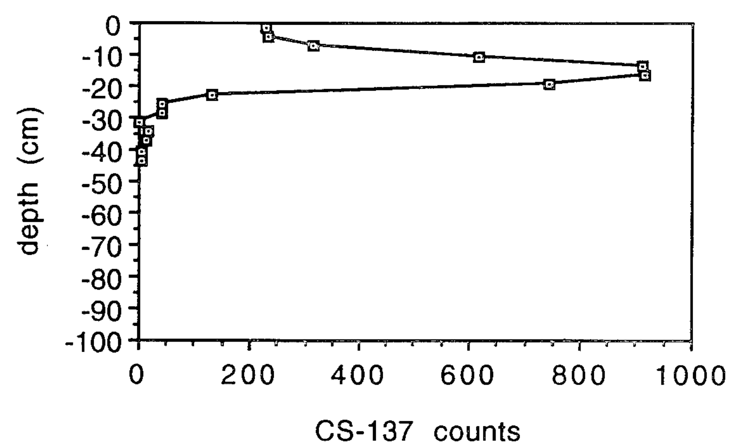

Pond 2 site 1
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
200
400
600
800
CS-137 counts

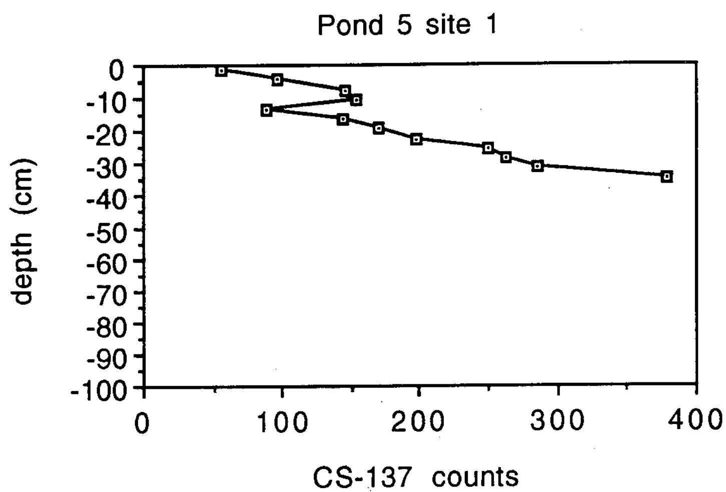

Pond 2 site 2
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
200
400
600
800
1000
Cs-137 counts

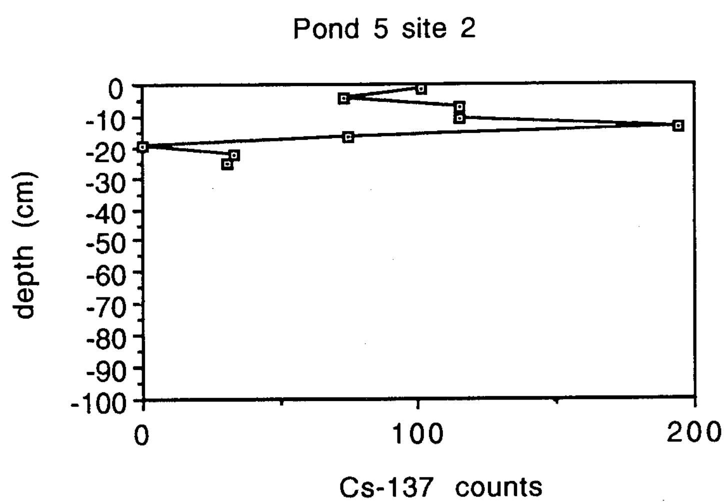
Pond 3 site 1



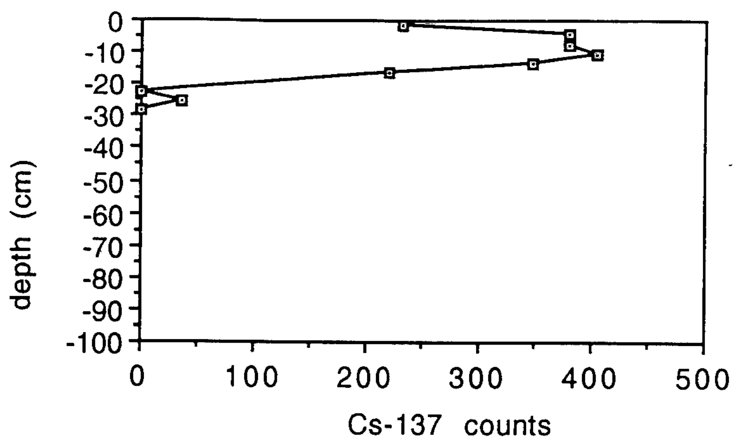
Pond 3 site 2



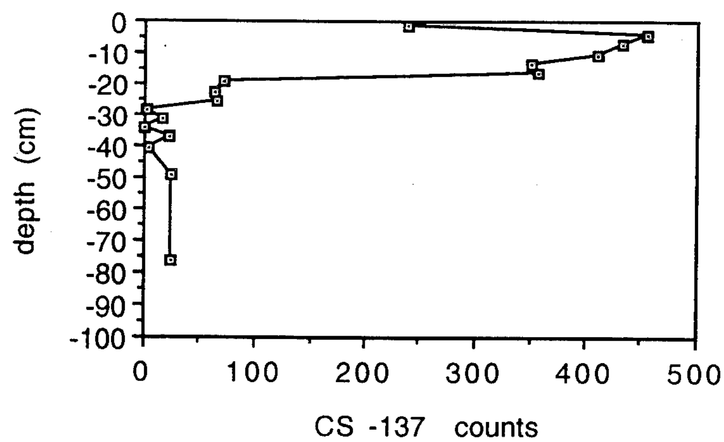

Pond 5 site 1
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
depth (cm)
CS-137 counts


Pond 5 site 2
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
depth (cm)
Cs-137 counts

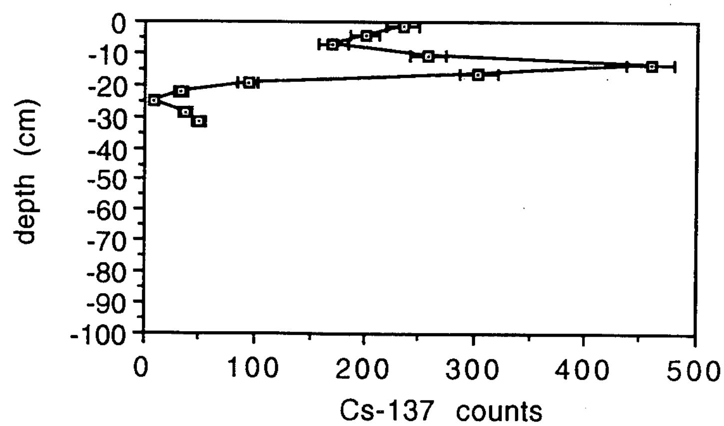
Pond 6 site 1

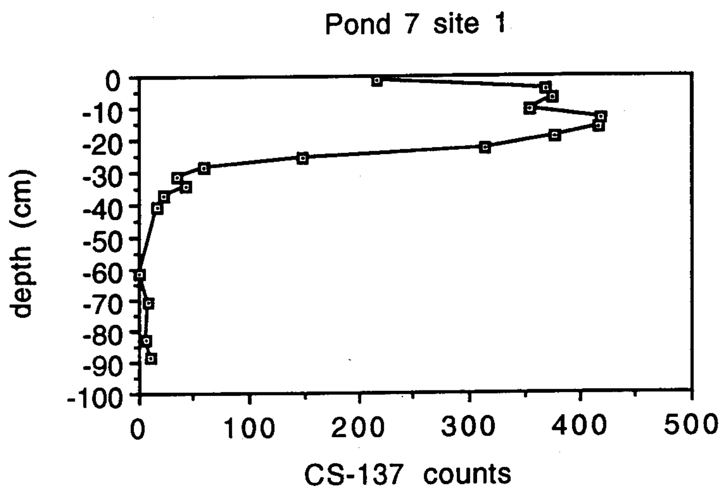


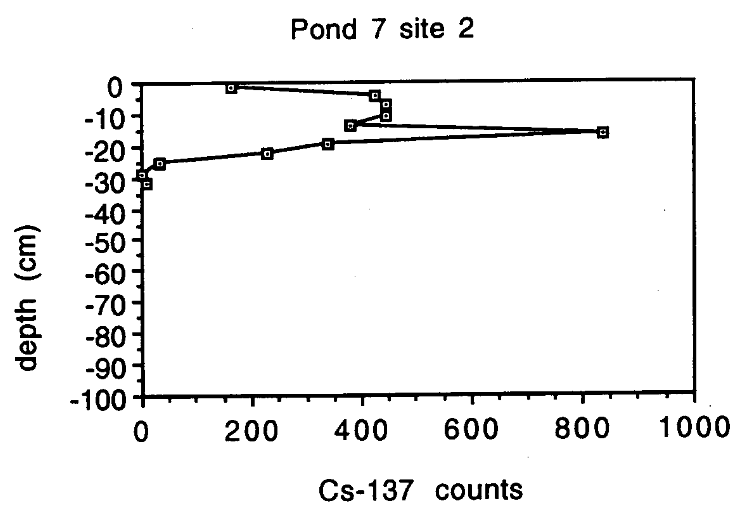
Pond 6 site 2

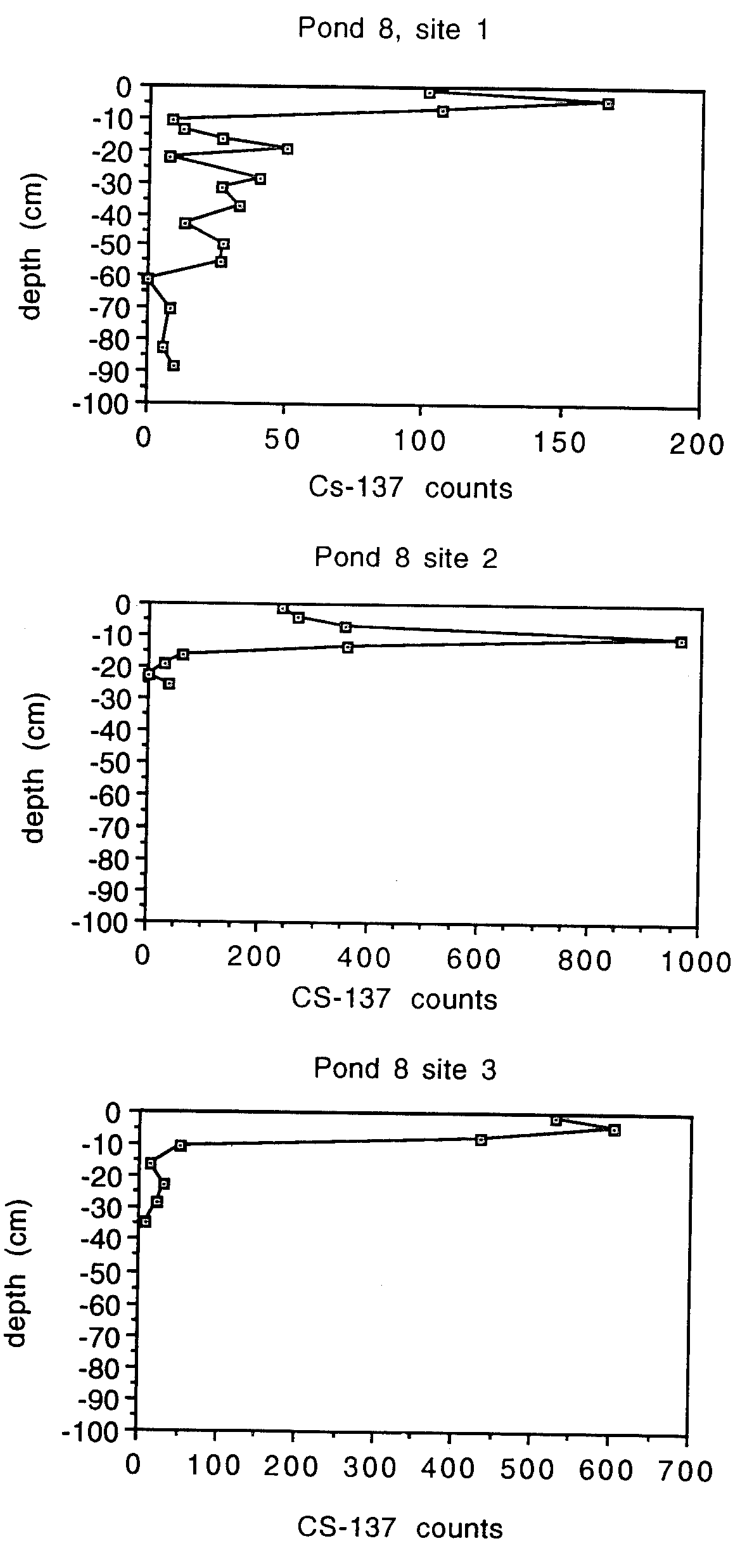


Pond 6 site 3

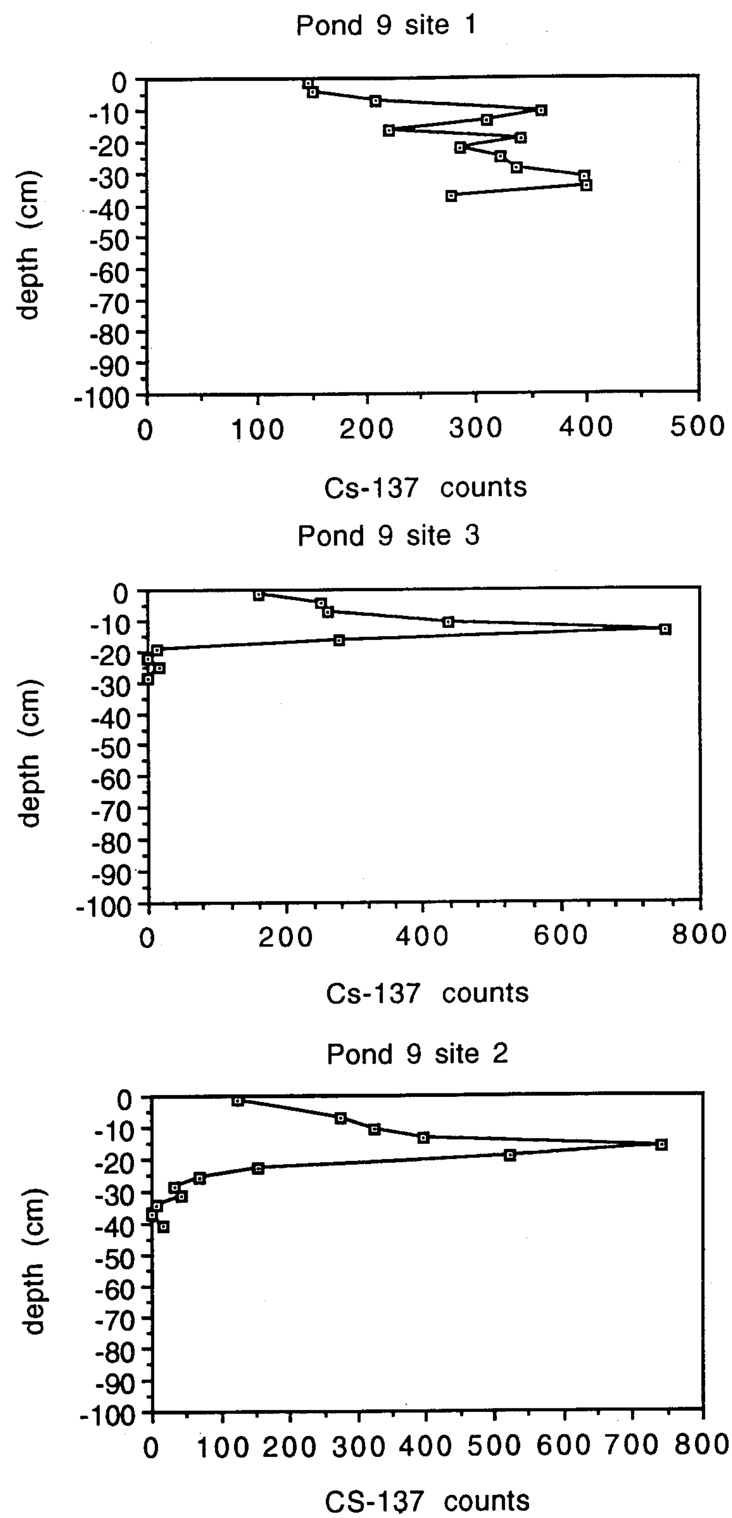



Pond 7 site 1
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
500
CS-137 counts


Pond 7 site 2
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
200
400
600
800
1000
Cs-137 counts



Pond 8, site 1
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
50
100
150
200
Cs-137 counts
Pond 8 site 2
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
200
400
600
800
1000
CS-137 counts
Pond 8 site 3
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
500
600
700
CS-137 counts


Pond 9 site 1
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
500
Cs-137 counts
Pond 9 site 3
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
200
400
600
800
Cs-137 counts
Pond 9 site 2
depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
100
200
300
400
500
600
700
800
CS-137 counts

Appendix C
Bulk Density and Moisture Content of 1993 Samples

Wetland 1, Site 1		
Depth, cm	**Bulk Density, g/cm^3**	**Percent Moisture**
0-3	0.842	48.9
3-6	0.584	45.2
6-9	0.984	39.9
9-12	1.308	26.1
12-15	1.097	26.0
15-18	1.399	25.3
18-21	1.219	24.2
21-24	1.377	26.2
24-27	1.107	26.0
27-30	1.568	26.9
30-33	0.869	27.5
33-36	1.228	26.6
36-39	1.204	26.3
39-42	1.338	26.7
42-45	0.959	27.2
45-48	1.177	26.2
48-51	1.002	26.8
51-54	0.882	27.5
54-57	1.124	27.6
57-60	1.323	23.7

(Continued)

Wetland 1, Site 1 (Concluded)

Depth, cm	Bulk Density, g/cm^3	Percent Moisture
60-63	0.863	25.7
63-66	0.962	28.0
66-69	1.220	27.6
69-72	1.005	25.5
72-75	1.296	24.4
75-78	1.303	24.1
78-81	1.283	23.3
81-84	1.288	22.8
84-87	1.111	22.4
87-90	1.436	20.5
90-93	1.536	20.3
93-96	1.446	20.1
96-99	1.526	19.5

Wetland 1, Site 2

Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.729	54.7
3-6	1.132	33.5
6-9	1.058	31.2
9-12	1.130	35.4
12-15	0.932	36.1
15-18	1.306	29.9
18-21	1.405	23.8
21-24	1.426	22.2
24-27	1.448	24.2
27-30	1.176	25.2
30-33	1.453	24.8
33-36	1.160	24.5
36-39	1.518	23.3
39-42	1.277	23.5
42-45	1.292	24.1
45-48	1.286	24.7

Wetland 2, Site 1		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.526	60.3
3-6	0.766	48.9
6-9	0.929	38.9
9-12	0.931	36.2
12-15	0.962	36.2
15-18	0.871	36.8
18-21	0.841	41.4
21-24	0.635	50.9
24-27	0.704	44.9
27-30	0.762	44.5
30-33	0.733	49.1
33-36	0.995	34.3
36-39	1.244	24.8
39-42	1.307	23.3
42-45	1.383	22.8
45-48	1.502	22.6
48-51	1.574	22.6

Wetland 2, Site 2

Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	1.117	43.4
3-6	0.922	36.5
6-9	0.798	41.0
9-12	0.712	45.9
12-15	0.786	41.3
15-18	0.947	34.5
18-21	1.226	34.5
21-24	1.386	23.9
24-27	1.344	20.9
27-30	1.430	20.6
30-33	1.430	22.3
33-36	1.482	21.7
36-39	1.349	23.5
39-42	1.265	23.5
42-45	1.189	25.0
45-48	1.087	26.1
48-51	1.122	25.7
51-54	1.201	22.8
54-57	1.272	22.9
57-60	1.343	23.9
60-63	1.008	26.3
63-66	1.217	25.2
66-69	1.231	23.6
69-72	1.382	21.3
72-75	1.549	21.2
75-78	1.177	20.5
78-81	1.308	21.3
81-84	1.426	21.4
84-87	1.324	21.4
97-90	1.411	20.9
90-93	1.496	19.9
93-96	1.481	20.4

Wetland 3, Site 1		
Depth, cm	**Bulk Density, g/cm^3**	**Percent Moisture**
0-3	0.715	43.7
3-6	0.635	41.6
6-9	0.925	39.8
9-12	0.881	36.2
12-15	1.046	33.8
15-18	0.936	37.6
18-21	1.495	22.6
21-24	1.261	23.6
24-27	1.407	24.1
27-30	1.609	25.2
30-33	1.139	25.7
33-36	1.045	25.4
36-39	1.222	24.3
39-42	1.533	23.2
42-45	1.382	22.7
45-48	1.299	22.2
48-51	1.556	20.3
51-54	1.418	19.7
54-57	1.400	20.4
57-60	1.058	28.5
60-63	1.421	22.9

Wetland 3, Site 2		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.643	40.0
3-6	0.655	38.5
6-9	0.823	37.7
9-12	0.838	38.0
12-15	0.710	41.0
15-18	0.572	42.2
18-21	0.974	33.9
21-24	1.270	24.8
24-27	1.392	22.0
27-30	1.540	21.3
30-33	1.290	20.1
33-36	1.771	18.1
36-39	1.587	19.0
39-42	1.331	20.0
42-45	1.233	20.4
45-48	1.564	21.3
48-51	1.476	22.1
51-54	1.285	22.1
54-57	1.144	21.2

Wetland 5, Site 1		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.734	33.4
3-6	1.083	31.4
6-9	1.042	31.6
9-12	1.076	30.1
12-15	1.186	28.8
15-18	1.131	28.9
18-21	1.060	31.7
21-24	0.837	32.7
24-27	1.071	32.0
27-30	0.886	33.1
30-33	0.953	32.9
33-36	0.983	35.4

Wetland 5, Site 2		
Depth, cm	**Bulk Density, g/cm^3**	**Percent Moisture**
0-3	0.813	37.0
3-6	0.718	36.3
6-9	0.695	40.1
9-12	0.784	41.8
12-15	0.659	40.1
15-18	1.377	24.1
18-21	1.524	17.8
21-24	1.259	22.0
24-27	1.377	23.6
27-30	1.202	25.1
30-33	1.188	25.5
33-36	1.165	24.8
36-39	1.279	22.4
39-42	1.280	22.9
42-45	1.247	22.7
45-48	1.231	22.7
48-51	1.567	20.6

Wetland 6, Site 1		
Depth, cm	**Bulk Density, g/cm^3**	**Percent Moisture**
0-3	0.576	52.2
3-6	1.057	34.2
6-9	1.046	29.8
9-12	1.093	27.3
12-15	1.287	25.3
15-18	1.301	21.2
18-21	1.536	22.2
21-24	1.557	22.2
24-27	1.345	22.8
27-30	1.299	22.5
30-33	1.492	22.4
33-36	1.392	22.7
36-39	1.053	23.7
39-42	1.347	21.9
42-45	1.633	20.1
45-48	1.173	21.4
48-51	1.341	21.6
51-54	1.262	21.2
54-57	1.215	28.5
57-60	1.537	21.2
60-63	1.278	20.7
63-66	1.494	16.7
66-69	1.394	23.3
69-72	1.192	24.1
72-75	1.314	20.2
75-78	1.473	21.0
78-81	1.623	21.4

Wetland 6, Site 2		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.728	59.1
3-6	1.129	30.6
6-9	1.183	26.9
9-12	1.144	27.5
12-15	1.025	23.6
15-18	1.385	25.2
18-21	1.248	26.3
21-24	1.278	26.2
24-27	1.190	26.0
27-30	1.219	25.9
30-33	1.321	26.4
33-36	0.822	27.2
36-39	1.183	27.1
39-42	1.073	26.9
42-45	1.338	26.2
45-48	1.324	26.7
48-51	1.225	27.0
51-54	1.348	27.3
54-57	1.350	19.8

Wetland 6, Site 3

Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	1.037	41.9
3-6	0.554	51.5
6-9	0.602	42.5
9-12	0.849	36.6
12-15	1.263	32.2
15-18	0.899	36.8
18-21	1.310	26.8
21-24	1.337	24.1
24-27	0.942	24.1
27-30	1.273	24.5
30-33	0.915	24.0
33-36	1.216	23.1
36-39	1.103	27.4
39-42	0.892	34.7

Wetland 7, Site 1		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.633	56.6
3-6	0.948	41.5
6-9	0.941	34.3
9-12	1.029	32.4
12-15	1.231	30.0
15-18	1.170	24.3
18-21	1.372	22.1
21-24	1.462	22.4
24-27	1.260	22.9
27-30	1.408	23.6
30-33	1.383	23.8
33-36	1.211	39.7
36-39	1.322	24.8
39-42	1.301	25.1
42-45	1.374	22.3
45-48	1.163	26.1
48-51	1.438	25.1
51-54	1.066	26.9
54-57	1.272	25.3
57-60	1.274	23.6
60-63	1.340	24.0
63-66	1.256	24.1
66-69	1.293	24.0
69-72	1.364	23.9
72-75	1.278	23.1
75-78	1.410	22.2

Wetland 7, Site 2		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.449	55.7
3-6	1.014	35.5
6-9	1.252	27.9
9-12	1.287	26.9
12-15	1.215	26.6
15-18	1.380	24.7
18-21	1.238	24.0
21-24	1.418	23.3
24-27	1.296	24.2
27-30	1.270	25.1
30-33	1.353	25.0
33-36	1.370	24.6
36-39	1.137	26.5
39-42	1.230	25.3
42-45	1.370	23.3
45-48	1.379	23.4
48-51	1.333	22.6
51-54	1.453	22.7
54-57	1.299	23.4
57-60	0.884	23.6

Wetland 8, Site 1		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.365	51.8
3-6	0.561	35.5
6-9	0.755	35.8
9-12	1.009	25.8
12-15	1.420	24.3
15-18	1.322	22.8
18-21	1.226	22.6
21-24	1.282	26.8
24-27	1.326	28.1
27-30	1.049	27.3
30-33	1.284	27.0
33-36	1.337	26.9
36-39	1.091	27.5
39-42	1.162	28.1
42-45	1.142	29.1
45-48	1.197	29.0
48-51	1.167	30.1
51-54	1.081	28.1
54-57	0.993	30.2
57-60	1.021	
60-63	1.213	27.4
63-66	0.989	29.0
66-69	0.935	26.1
69-72	1.152	27.0
72-75	0.939	26.4
75-78	1.296	26.7
78-81	1.283	25.8
81-84	1.320	24.8
84-87	1.182	23.6
87-90	1.236	27.0
90-93	1.174	28.7

Wetland 8, Site 2		
Depth, cm	**Bulk Density, g/cm^3**	**Percent Moisture**
0-3	0.343	71.4
3-6	0.474	56.2
6-9	0.349	59.1
9-12	0.434	59.4
12-15	0.748	44.5
15-18	0.978	35.1
18-21	1.069	33.0
21-24	1.007	33.1
24-27	0.780	34.1
27-30	1.038	33.6
30-33	1.078	31.7
33-36	1.095	29.2
36-39	1.077	25.4
39-42	1.214	27.7
42-45	1.064	27.1
45-48	1.248	28.0
48-51	1.160	28.7
51-54	1.034	30.7
54-57	1.036	30.5
57-60	0.997	28.6
60-63	0.930	30.7
63-66	0.992	30.5
66-69	1.114	26.8
69-72	1.235	22.1
72-75	1.054	26.1
75-78	1.090	25.9
78-81	1.239	26.0
81-84	1.573	26.2
84-87	0.975	26.3
87-90	1.110	25.2
90-93	1.029	25.7

Wetland 8, Site 3		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.595	
3-6	0.409	55.8
6-9	0.893	39.7
9-12	1.168	31.4
12-15	0.777	40.8
15-18	0.886	35.6
18-21	0.855	35.9
21-24	0.898	32.5
24-27	1.180	29.3
27-30	1.130	28.5
30-33	1.049	31.0
33-36	1.192	29.4
36-39	0.980	31.4
39-42	1.068	28.2
42-45	0.992	31.4
45-48	0.947	28.8
48-51	0.964	27.9
51-54	0.882	28.5

Wetland 9, Site 1		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.577	56.0
3-6	0.584	46.5
6-9	0.815	40.1
9-12	1.150	38.2
12-15	0.772	43.0
15-18	0.625	42.8
18-21	0.776	42.4
21-24	0.617	47.5
24-27	0.686	45.8
27-30	0.649	46.0
30-33	0.785	45.0
33-36	0.647	44.1
36-39	0.736	42.5

Wetland 9, Site 2		
Depth, cm	Bulk Density, g/cm^3	Percent Moisture
0-3	0.370	44.8
3-6	0.552	46.0
6-9	0.570	47.5
9-12	0.530	49.5
12-15	0.579	49.4
15-18	0.535	47.1
18-21	0.658	42.2
21-24	0.880	35.6
24-27	0.848	33.8
27-30	0.970	30.7
30-33	1.001	27.8
33-36	1.075	28.4
36-39	1.060	24.8
39-42	1.165	24.7
42-45	1.008	26.2
45-48	1.212	28.1
48-51	1.094	26.1
51-54	1.113	26.6
54-57	1.023	26.8
57-60	1.047	27.4
60-63	0.971	29.4

Appendix D
Grain-Size Analyses of 1993 Samples

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 1 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-6 DATE: 19 SEP 94

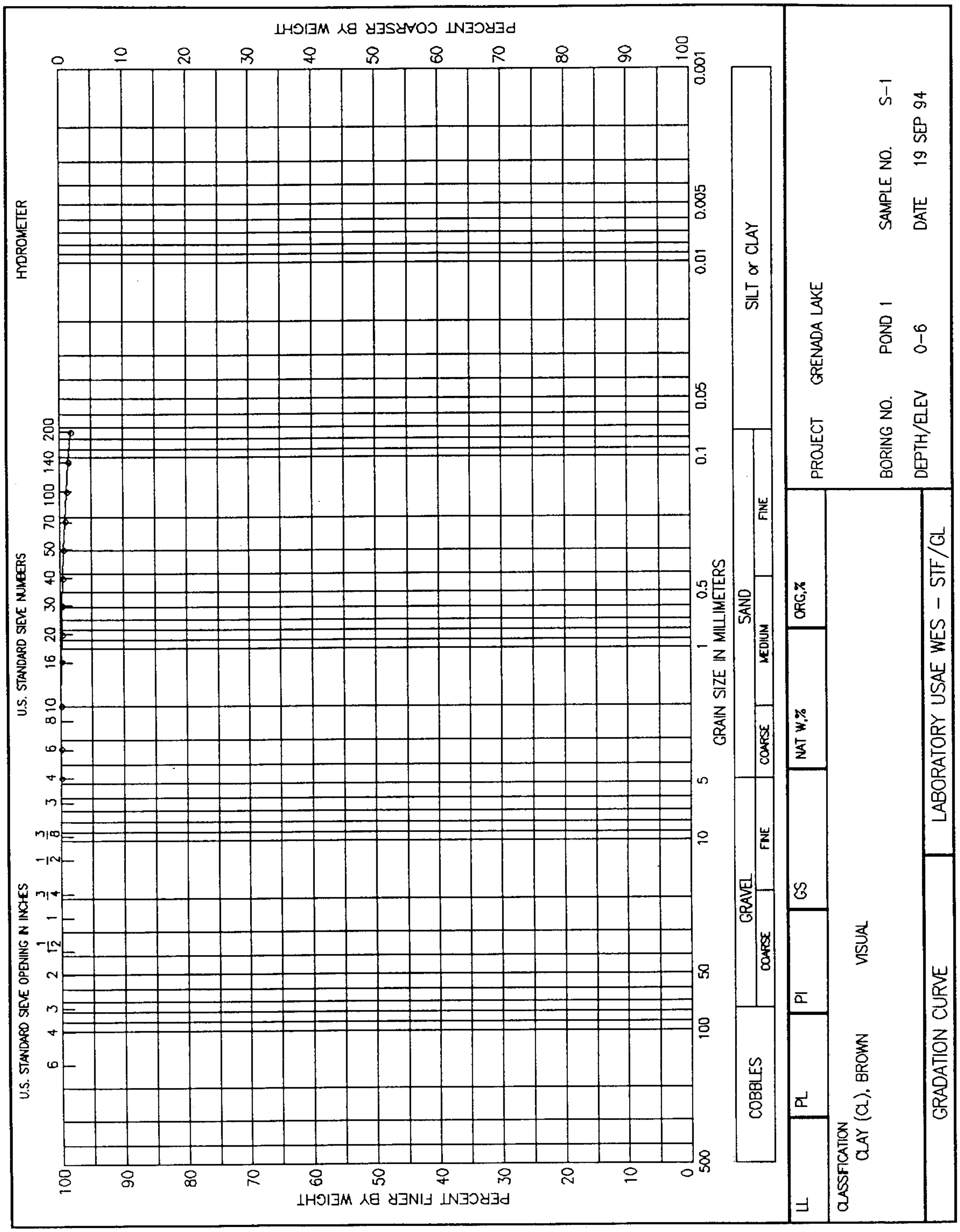
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 108
CLAY (CL), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 73.9 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.7	.3
.2	No 30	.600	99.7	.3
.3	No 40	.425	99.6	.4
.4	No 50	.300	99.5	.5
.6	No 70	.212	99.2	.8
.8	No 100	.150	98.9	1.1
1.0	No 140	.106	98.6	1.4
1.3	No 200	.075	98.2	1.8

PERCENT GRAVEL = .0
PERCENT SAND = 1.8
PERCENT FINES = 98.2

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CL), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 1
SAMPLE NO. S-1
DEPTH/ELEV 0-6
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 1 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-9 DATE: 19 SEP 94

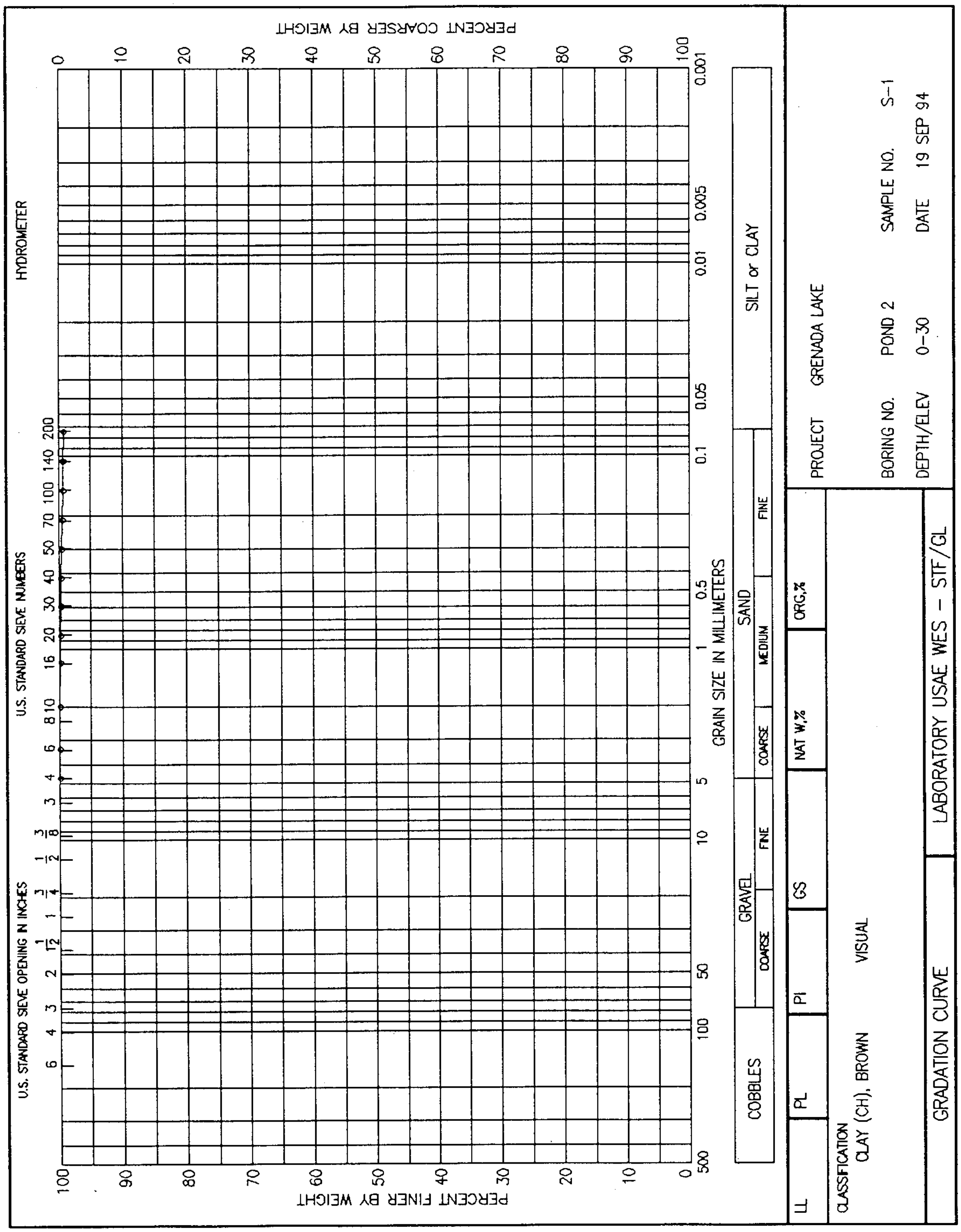
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 118
CLAY (CL), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 79.6 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.0	No 20	.850	100.0	.0
.1	No 30	.600	99.9	.1
.1	No 40	.425	99.9	.1
.1	No 50	.300	99.9	.1
.2	No 70	.212	99.7	.3
.4	No 100	.150	99.5	.5
.6	No 140	.106	99.2	.8
.8	No 200	.075	99.0	1.0

PERCENT GRAVEL = .0
PERCENT SAND = 1.0
PERCENT FINES = 99.0

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ 3/8 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 2
SAMPLE NO. S-1
DEPTH/ELEV 0-30
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 2   SAMPLE: S-1   DF: MD6194 .DAT
DEPTH: 0-30   DATE: 19 SEP 94

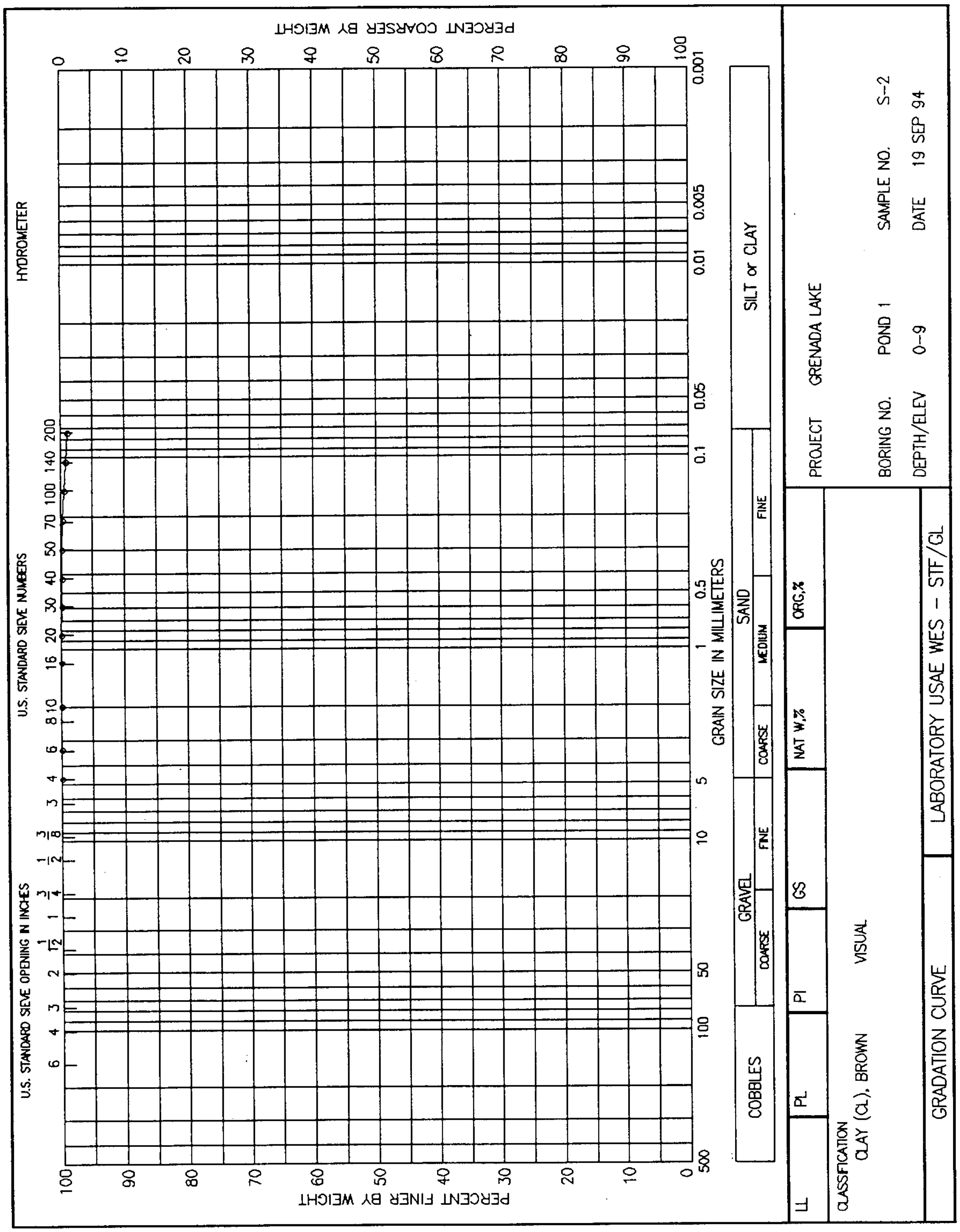
NO-LIMITS-RAN   GS: .00   WC: .00
CLASSIFICATION: 128
CLAY (CH), BROWN   VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 87.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.1	No 20	.850	99.9	.1
.2	No 30	.600	99.8	.2
.2	No 40	.425	99.8	.2
.3	No 50	.300	99.7	.3
.4	No 70	.212	99.5	.5
.5	No 100	.150	99.4	.6
.5	No 140	.106	99.4	.6
.6	No 200	.075	99.3	.7

PERCENT GRAVEL = .0
PERCENT SAND = .7
PERCENT FINES = 99.3

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CL), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 1
SAMPLE NO. S-2
DEPTH/ELEV 0-9
DATE 19 SEP 94
LABORATORY USAE WES - STF/GL
GRADATION CURVE

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 2 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-30 DATE: 19 SEP 94

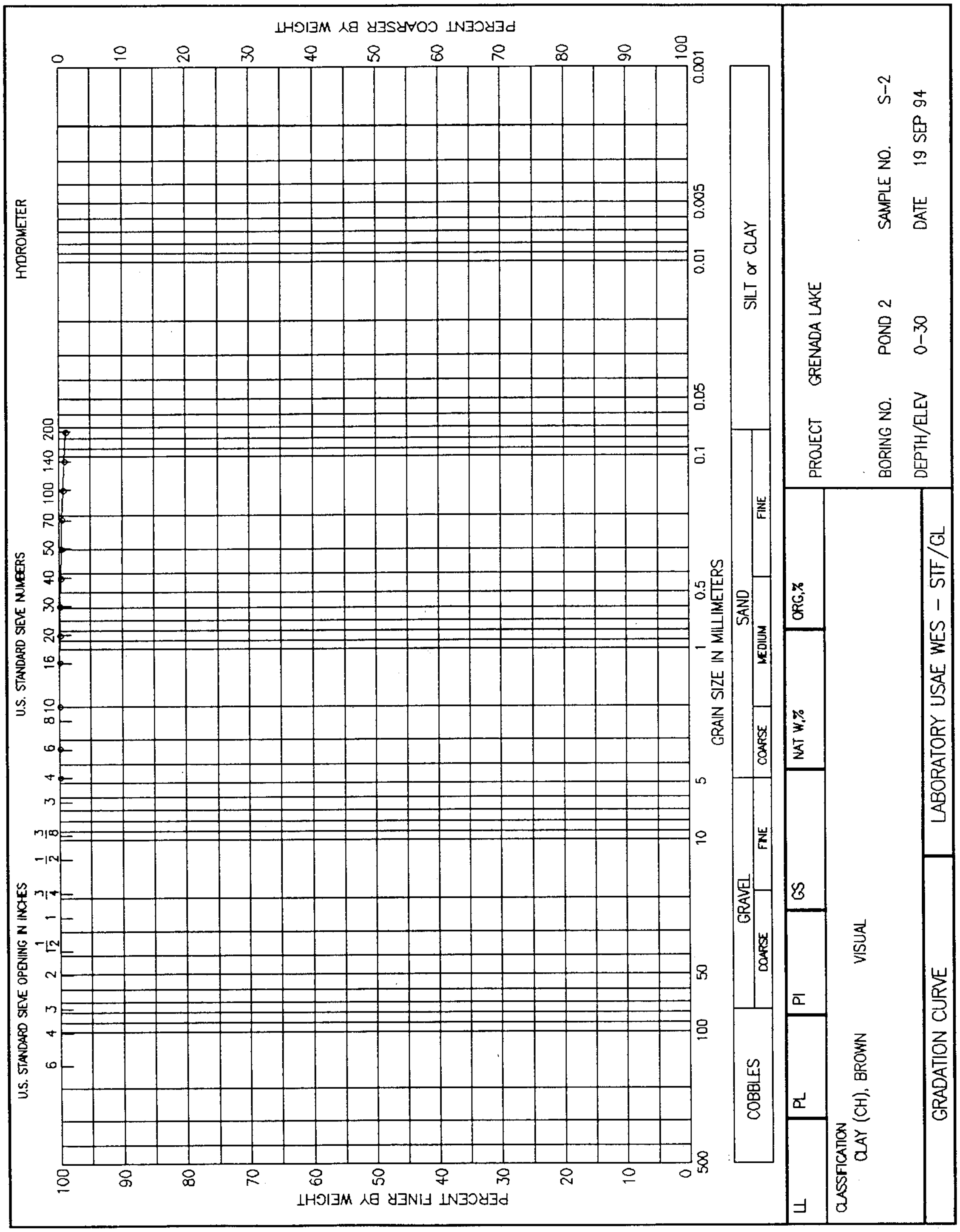
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 138
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 98.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.1	No 20	.850	99.9	.1
.1	No 30	.600	99.9	.1
.2	No 40	.425	99.8	.2
.3	No 50	.300	99.7	.3
.4	No 70	.212	99.6	.4
.6	No 100	.150	99.4	.6
.8	No 140	.106	99.2	.8
1.0	No 200	.075	99.0	1.0

PERCENT GRAVEL = .0
PERCENT SAND = 1.0
PERCENT FINES = 99.0

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 2
SAMPLE NO. S-2
DEPTH/ELEV 0-30
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 3 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-12 DATE: 19 SEP 94

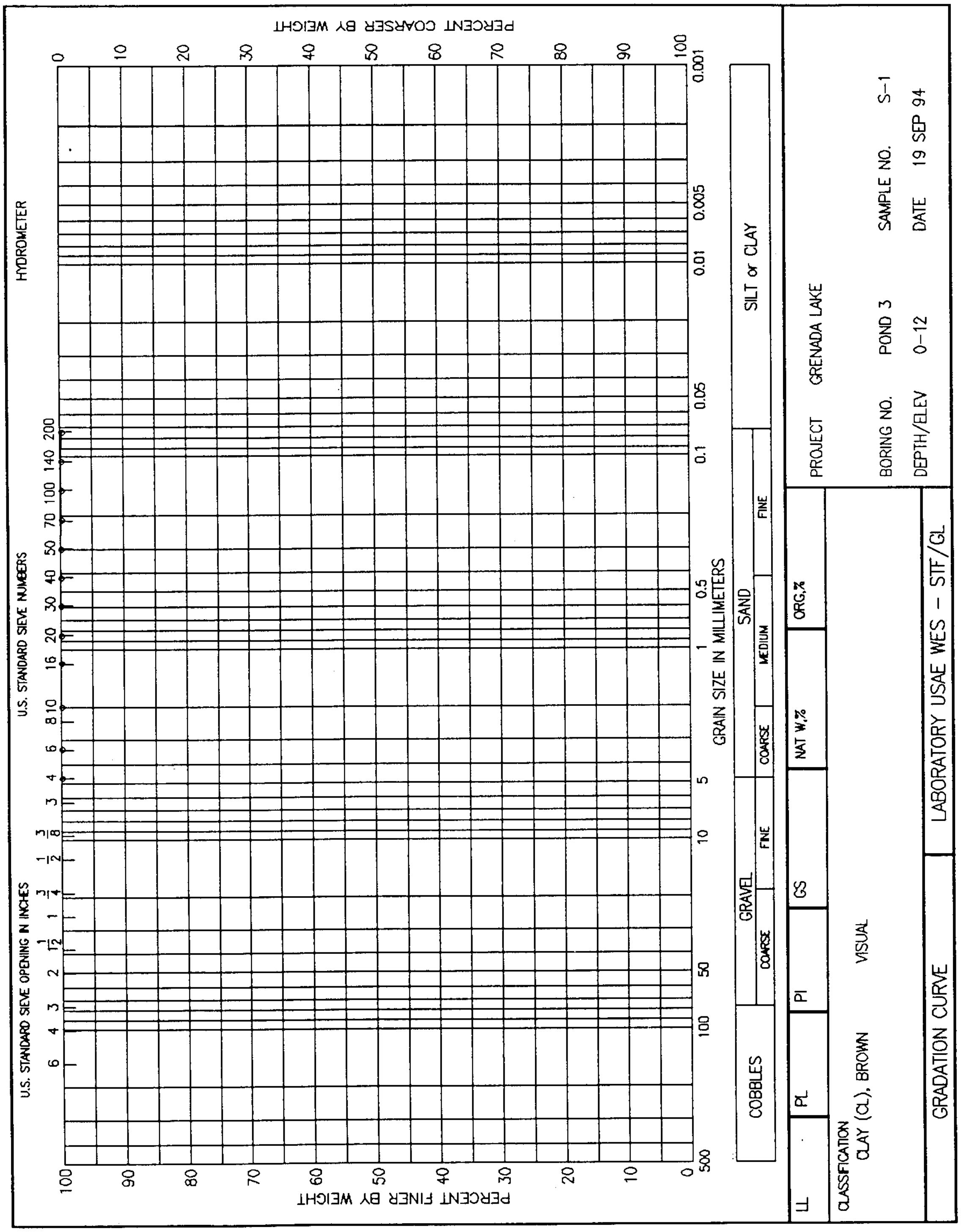
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 148
CLAY (CL), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 85.9 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.0	No 20	.850	100.0	.0
.0	No 30	.600	100.0	.0
.0	No 40	.425	100.0	.0
.0	No 50	.300	100.0	.0
.1	No 70	.212	99.9	.1
.1	No 100	.150	99.9	.1
.1	No 140	.106	99.9	.1
.2	No 200	.075	99.8	.2

PERCENT GRAVEL = .0
PERCENT SAND = .2
PERCENT FINES = 99.8

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
PROJECT GRENADA LAKE
CLASSIFICATION
CLAY (CL), BROWN
VISUAL
BORING NO. POND 3
SAMPLE NO. S-1
DEPTH/ELEV 0-12
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 3 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-15 DATE: 19 SEP 94

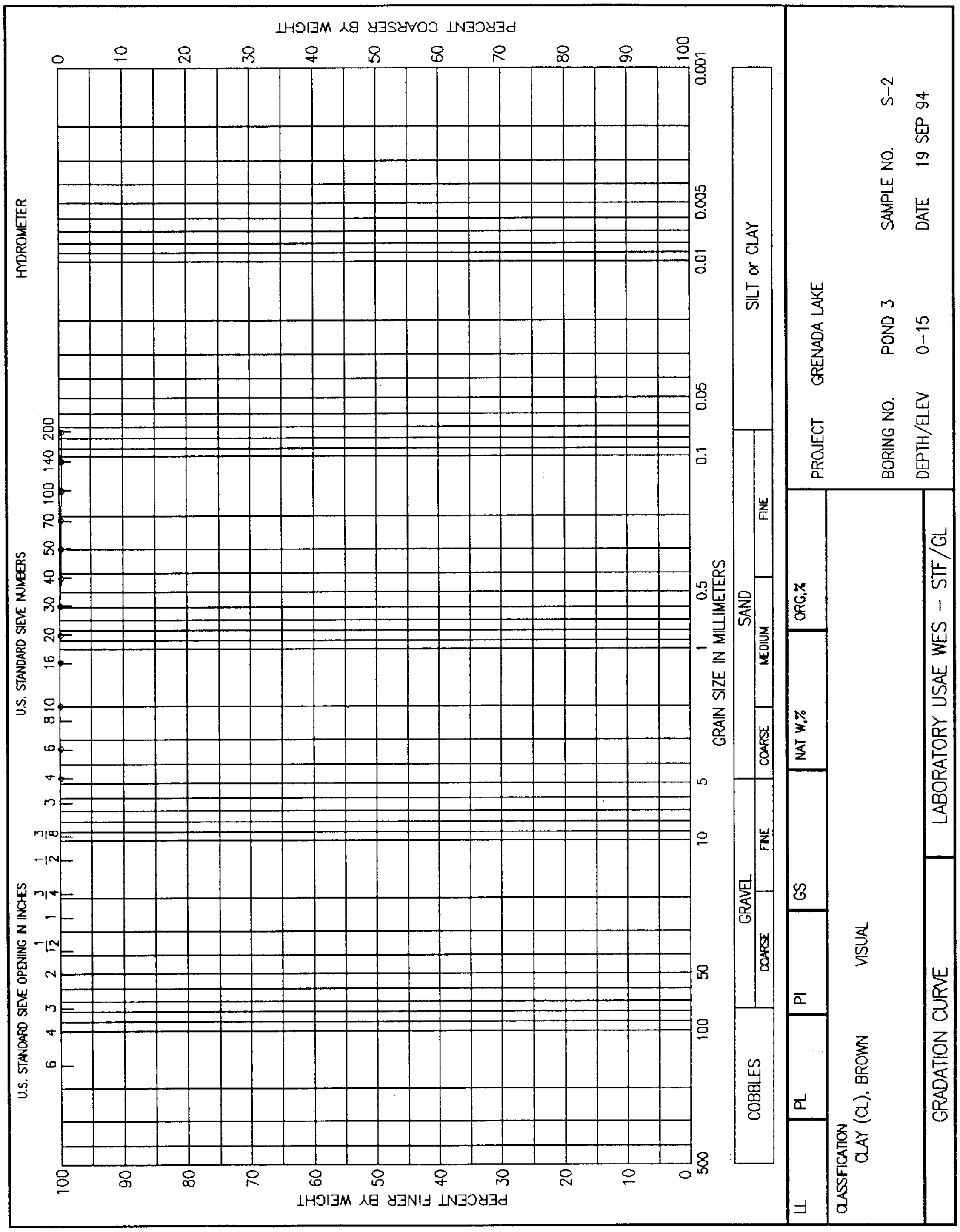
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 158
CLAY (CL), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 71.5 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.0	No 20	.850	100.0	.0
.0	No 30	.600	100.0	.0
.1	No 40	.425	99.9	.1
.1	No 50	.300	99.9	.1
.1	No 70	.212	99.9	.1
.2	No 100	.150	99.7	.3
.2	No 140	.106	99.7	.3
.2	No 200	.075	99.7	.3

PERCENT GRAVEL = .0
PERCENT SAND = .3
PERCENT FINES = 99.7

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1 1/2 1 3/4 1/2 3/8 3
U.S. STANDARD SIEVE NUMBERS
4 6 8 10 16 20 30 40 50 70 100 140 200
HYDROMETER
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CL), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 3
SAMPLE NO. S-2
DEPTH/ELEV 0-15
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 5 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-33 DATE: 19 SEP 94

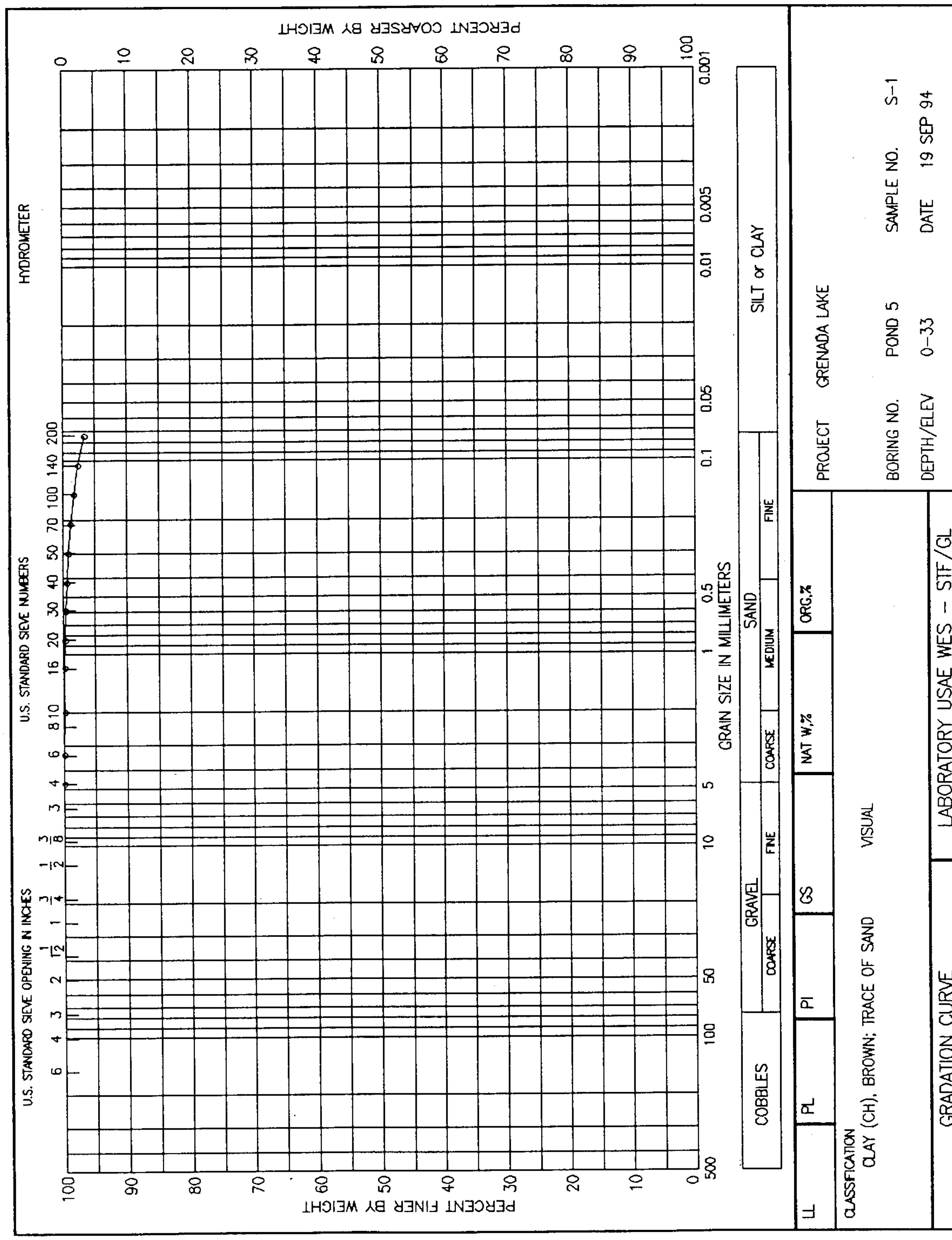
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 168
CLAY (CH), BROWN; TRACE OF SAND VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 91.1 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.1	No 10	2.000	99.9	.1
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.8	.2
.3	No 30	.600	99.7	.3
.5	No 40	.425	99.5	.5
.7	No 50	.300	99.2	.8
1.0	No 70	.212	98.9	1.1
1.5	No 100	.150	98.4	1.6
2.1	No 140	.106	97.7	2.3
3.0	No 200	.075	96.7	3.3

PERCENT GRAVEL = .0
PERCENT SAND = 3.3
PERCENT FINES = 96.7

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1 1/2 1 3/4 1/2 3/8 3
U.S. STANDARD SIEVE NUMBERS
4 6 8 10 16 20 30 40 50 70 100 140 200
HYDROMETER
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN; TRACE OF SAND
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 5
SAMPLE NO. S-1
DEPTH/ELEV 0-33
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 5 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-12 DATE: 19 SEP 94

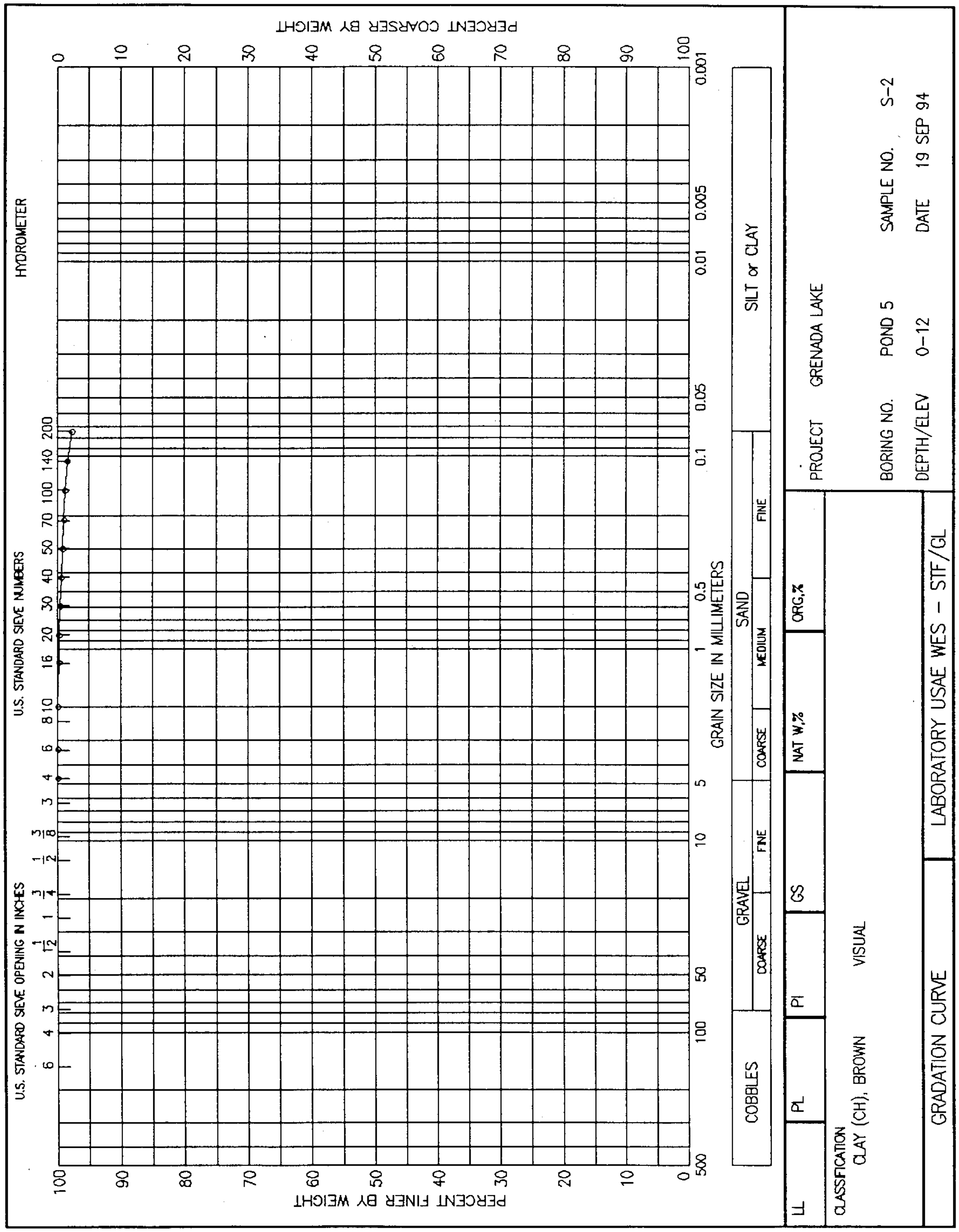
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 178
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 53.1 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.8	.2
.1	No 20	.850	99.8	.2
.2	No 30	.600	99.6	.4
.3	No 40	.425	99.4	.6
.4	No 50	.300	99.2	.8
.5	No 70	.212	99.1	.9
.6	No 100	.150	98.9	1.1
.8	No 140	.106	98.5	1.5
1.2	No 200	.075	97.7	2.3

PERCENT GRAVEL = .0
PERCENT SAND = 2.3
PERCENT FINES = 97.7

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1 1/2 1 3/4 1/2 3/8 3
U.S. STANDARD SIEVE NUMBERS
4 6 8 10 16 20 30 40 50 70 100 140 200
HYDROMETER
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
PROJECT GRENADA LAKE
BORING NO. POND 5
SAMPLE NO. S-2
DEPTH/ELEV 0-12
DATE 19 SEP 94
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 6 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-9 DATE: 19 SEP 94

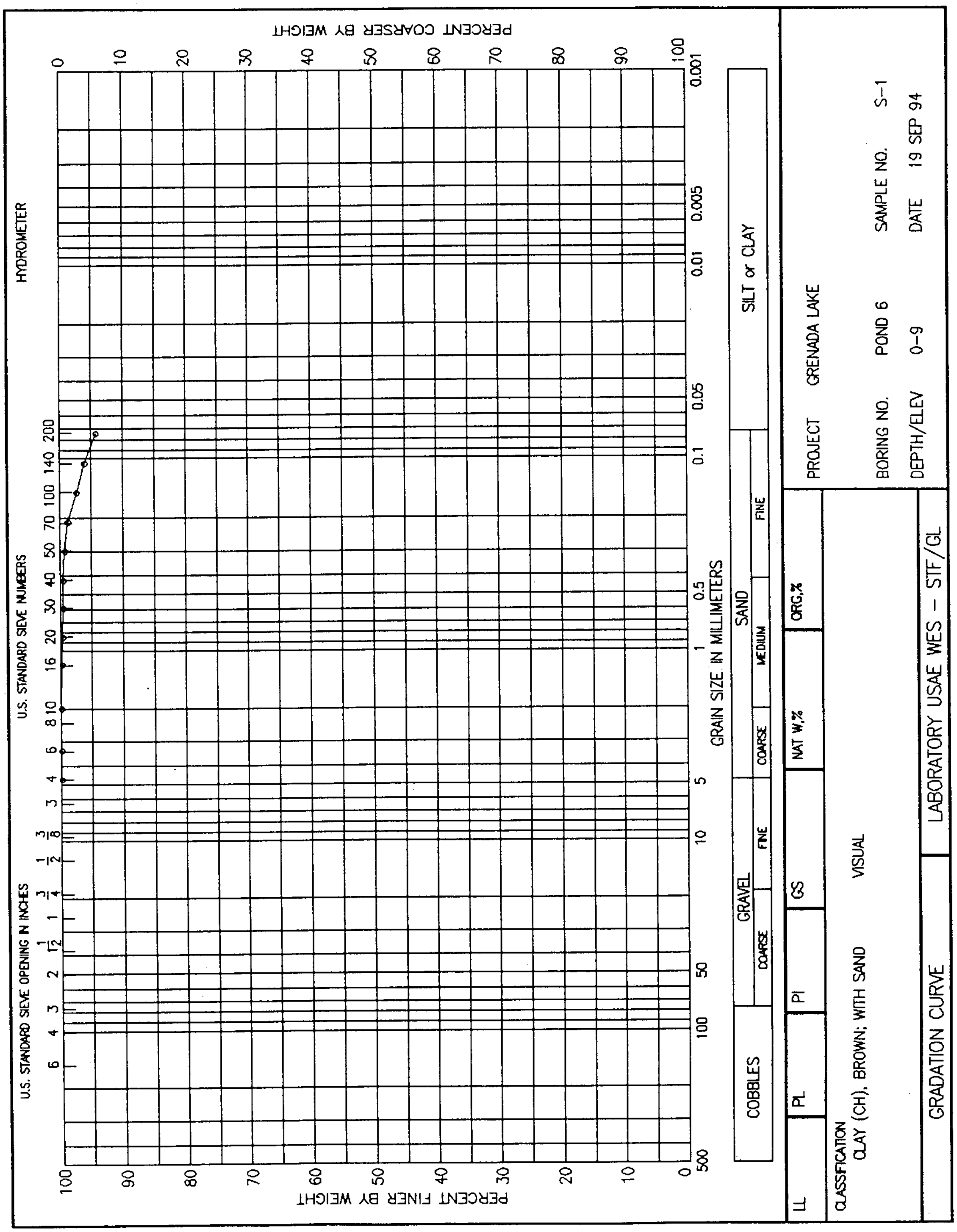
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 188
CLAY (CH), BROWN; WITH SAND VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 77.1 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.7	.3
.3	No 30	.600	99.6	.4
.3	No 40	.425	99.6	.4
.5	No 50	.300	99.4	.6
.9	No 70	.212	98.8	1.2
2.0	No 100	.150	97.4	2.6
3.0	No 140	.106	96.1	3.9
4.4	No 200	.075	94.3	5.7

PERCENT GRAVEL = .0
PERCENT SAND = 5.7
PERCENT FINES = 94.3

EDE


HYDROMETER
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN; WITH SAND
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 6
SAMPLE NO. S-1
DEPTH/ELEV 0-9
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 6　　SAMPLE: S-2　　DF: MD6194 .DAT
DEPTH: 0-3　　DATE: 19 SEP 94

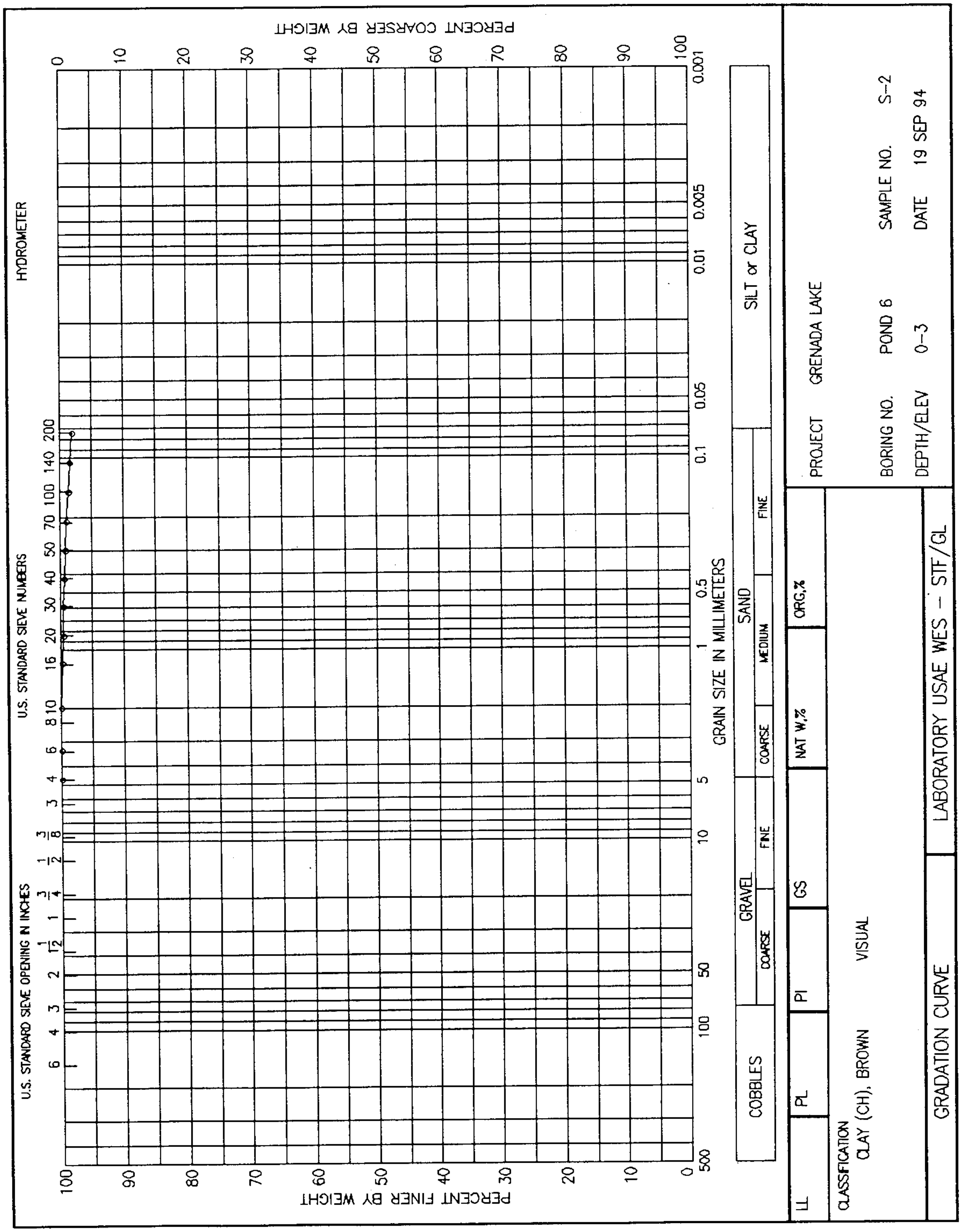
NO-LIMITS-RAN　GS: .00　WC: .00
CLASSIFICATION: 198
CLAY (CH), BROWN　VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 53.0 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.8	.2
.2	No 20	.850	99.6	.4
.2	No 30	.600	99.6	.4
.3	No 40	.425	99.4	.6
.4	No 50	.300	99.2	.8
.5	No 70	.212	99.1	.9
.7	No 100	.150	98.7	1.3
.8	No 140	.106	98.5	1.5
1.0	No 200	.075	98.1	1.9

PERCENT GRAVEL = .0
PERCENT SAND = 1.9
PERCENT FINES = 98.1

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 6
SAMPLE NO. S-2
DEPTH/ELEV 0-3
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 6 SAMPLE: S-3 DF: MD6194 .DAT
DEPTH: 0-12 DATE: 19 SEP 94

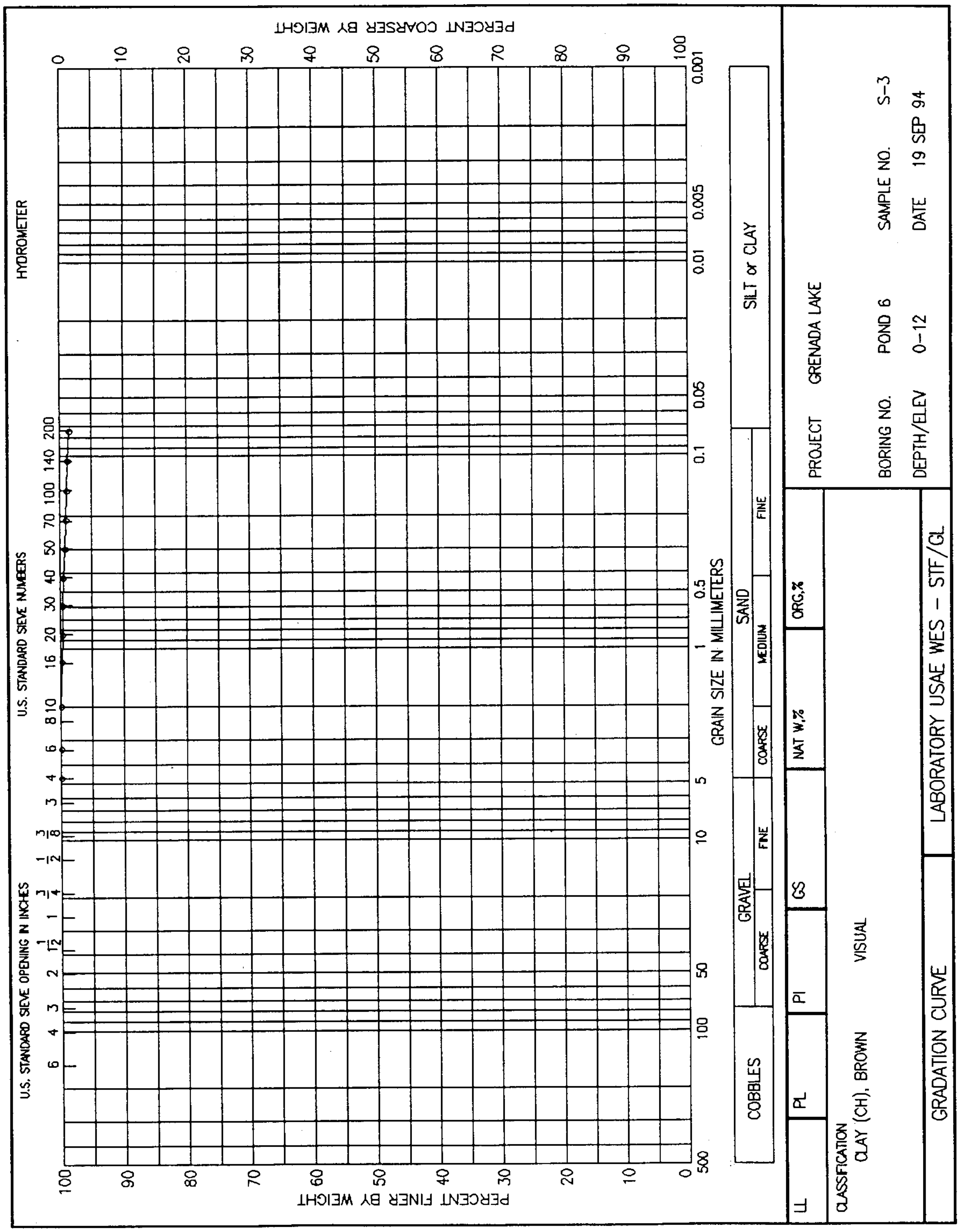
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 208
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 70.4 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.7	.3
.2	No 30	.600	99.7	.3
.3	No 40	.425	99.6	.4
.5	No 50	.300	99.3	.7
.6	No 70	.212	99.1	.9
.7	No 100	.150	99.0	1.0
.8	No 140	.106	98.9	1.1
1.0	No 200	.075	98.6	1.4

PERCENT GRAVEL = .0
PERCENT SAND = 1.4
PERCENT FINES = 98.6

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 6
SAMPLE NO. S-3
DEPTH/ELEV 0-12
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 7 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-12 DATE: 19 SEP 94

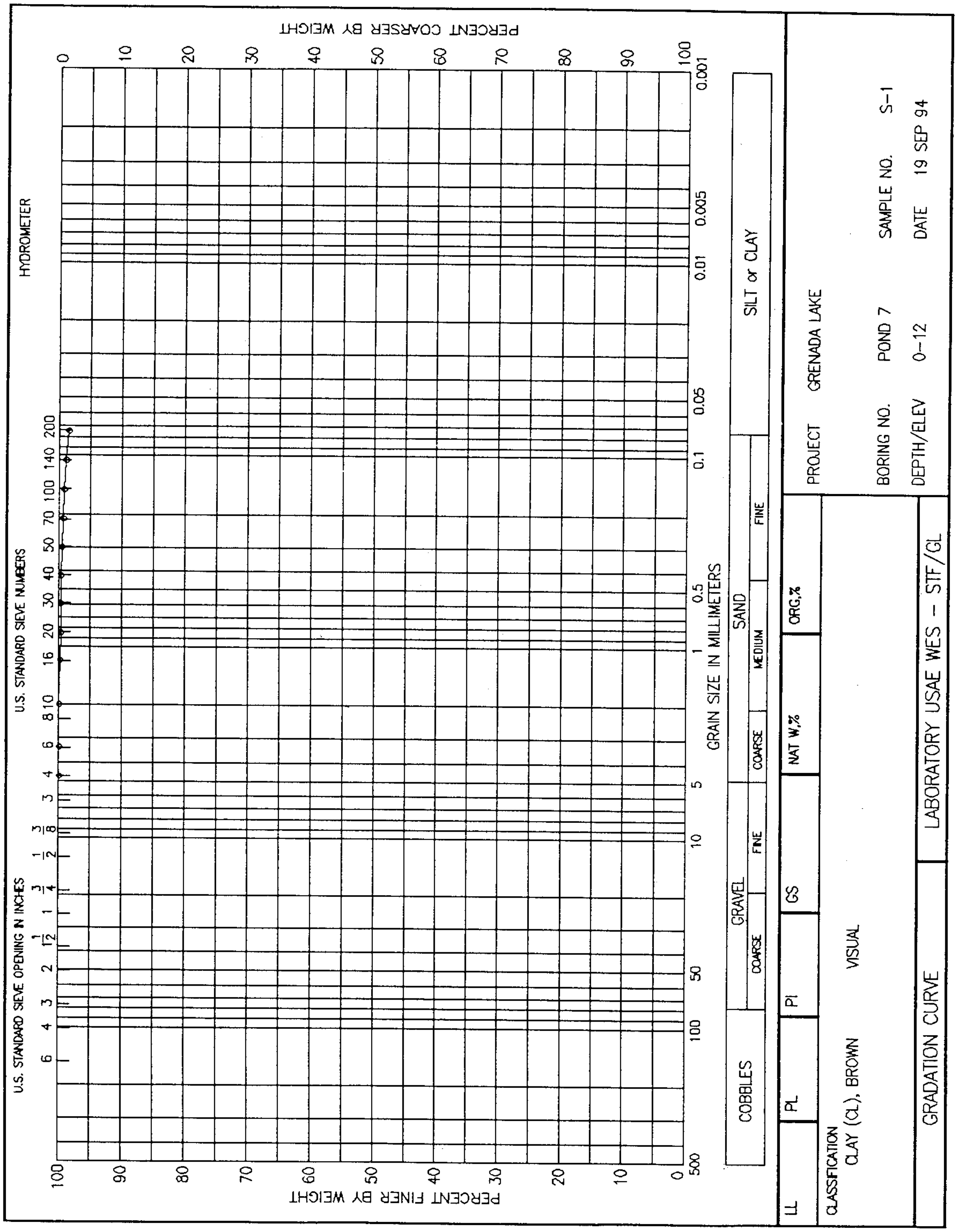
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 218
CLAY (CL), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 69.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.7	.3
.2	No 30	.600	99.7	.3
.2	No 40	.425	99.7	.3
.3	No 50	.300	99.6	.4
.4	No 70	.212	99.4	.6
.5	No 100	.150	99.3	.7
.7	No 140	.106	99.0	1.0
1.0	No 200	.075	98.6	1.4

PERCENT GRAVEL = .0
PERCENT SAND = 1.4
PERCENT FINES = 98.6

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CL), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 7
SAMPLE NO. S-1
DEPTH/ELEV 0-12
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 7 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-15 DATE: 19 SEP 94

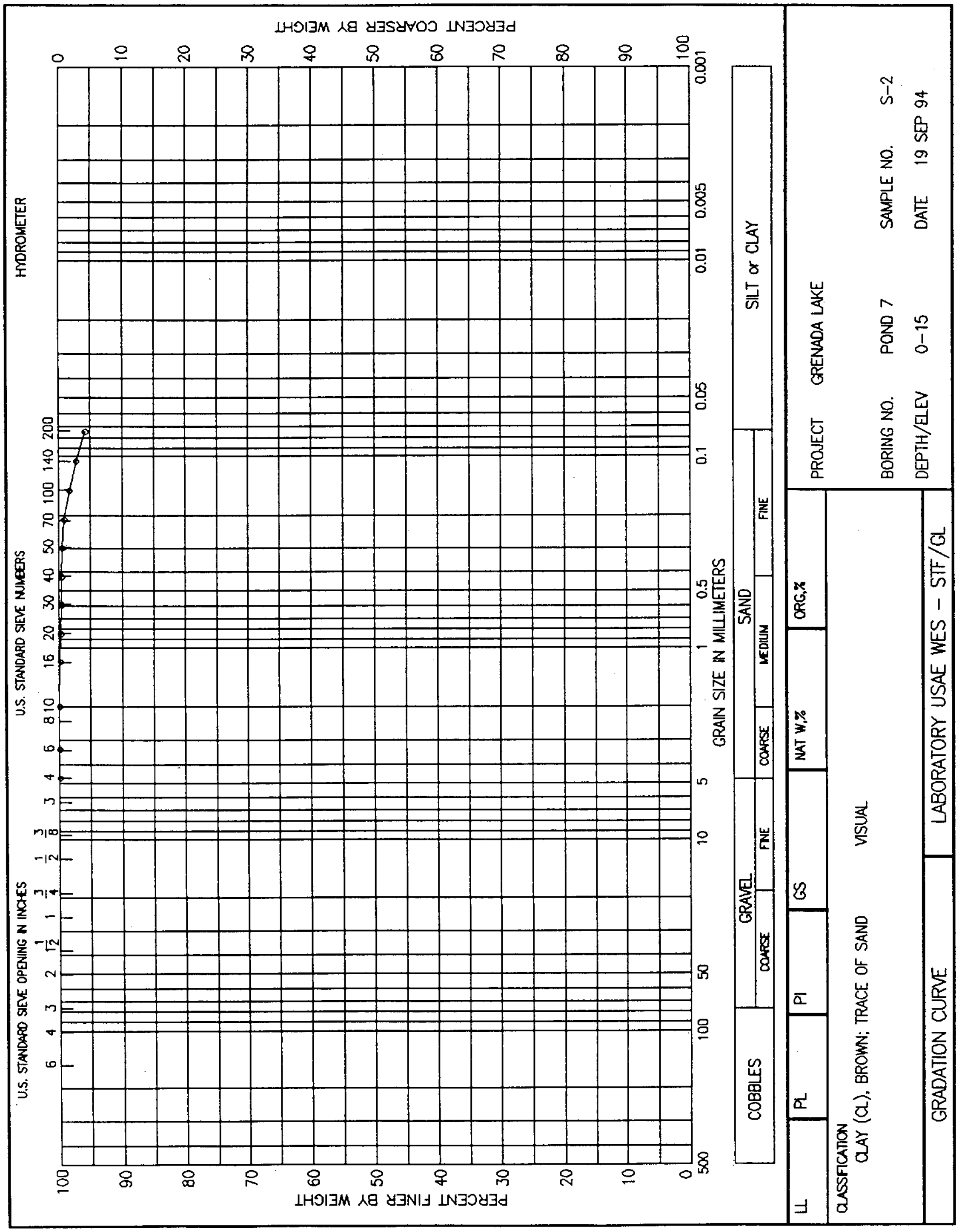
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 228
CLAY (CL), BROWN; TRACE OF SAND VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 91.5 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.2	No 20	.850	99.8	.2
.3	No 30	.600	99.7	.3
.3	No 40	.425	99.7	.3
.4	No 50	.300	99.6	.4
.7	No 70	.212	99.2	.8
1.5	No 100	.150	98.4	1.6
2.5	No 140	.106	97.3	2.7
3.8	No 200	.075	95.8	4.2

PERCENT GRAVEL = .0
PERCENT SAND = 4.2
PERCENT FINES = 95.8

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1 1/2 1 3/4 1/2 3/8 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CL), BROWN; TRACE OF SAND
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 7
SAMPLE NO. S-2
DEPTH/ELEV 0-15
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 8 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 3-6 DATE: 19 SEP 94

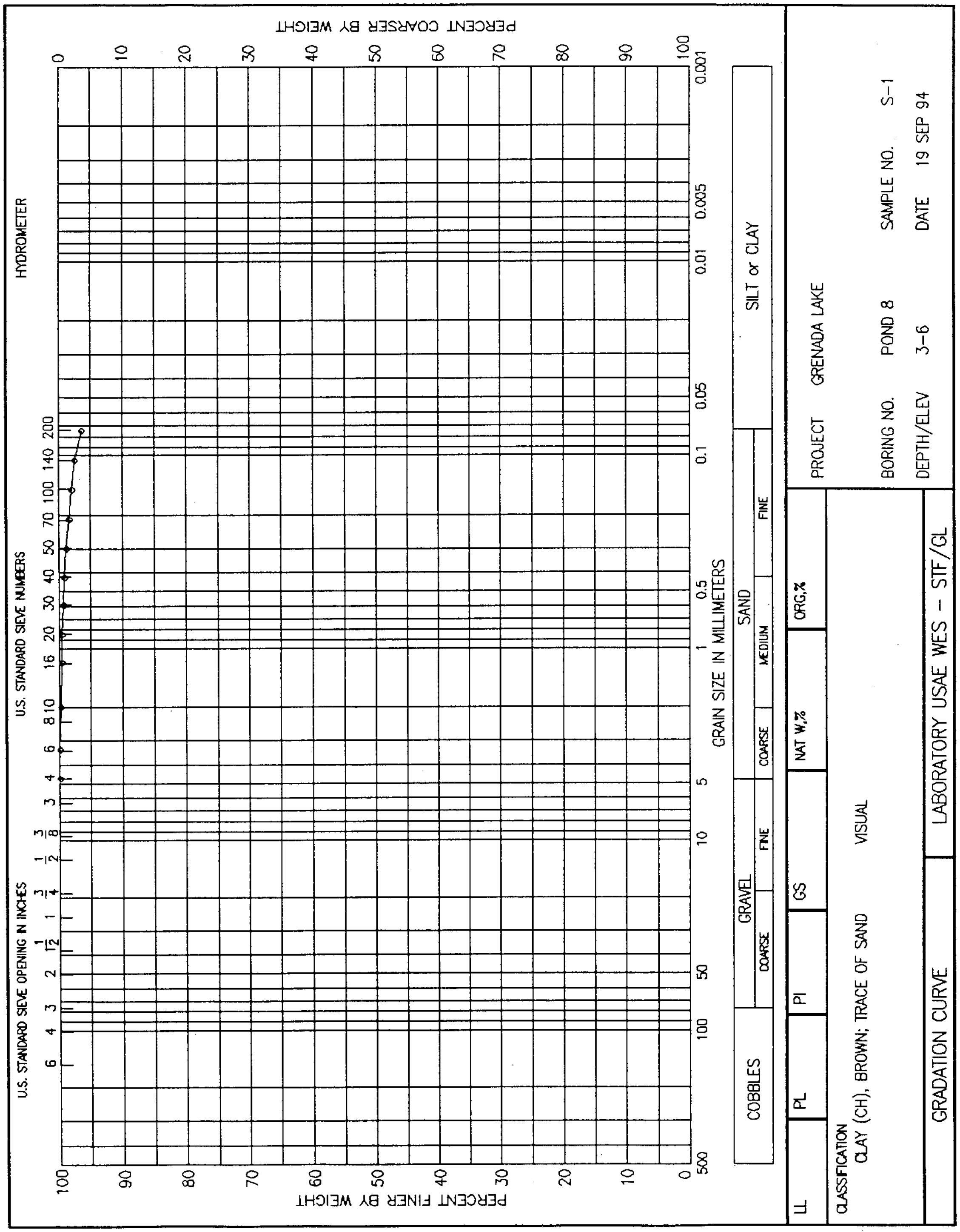
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 238
CLAY (CH), BROWN; TRACE OF SAND VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 65.0 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.1	No 10	2.000	99.8	.2
.2	No 16	1.180	99.7	.3
.2	No 20	.850	99.7	.3
.4	No 30	.600	99.4	.6
.5	No 40	.425	99.2	.8
.7	No 50	.300	98.9	1.1
1.0	No 70	.212	98.5	1.5
1.3	No 100	.150	98.0	2.0
1.6	No 140	.106	97.5	2.5
2.3	No 200	.075	96.5	3.5

PERCENT GRAVEL = .0
PERCENT SAND = 3.5
PERCENT FINES = 96.5

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
PROJECT GRENADA LAKE
BORING NO. POND 8
SAMPLE NO. S-1
DEPTH/ELEV 3-6
DATE 19 SEP 94
CLASSIFICATION
CLAY (CH), BROWN; TRACE OF SAND
VISUAL
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 8 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-9 DATE: 19 SEP 94

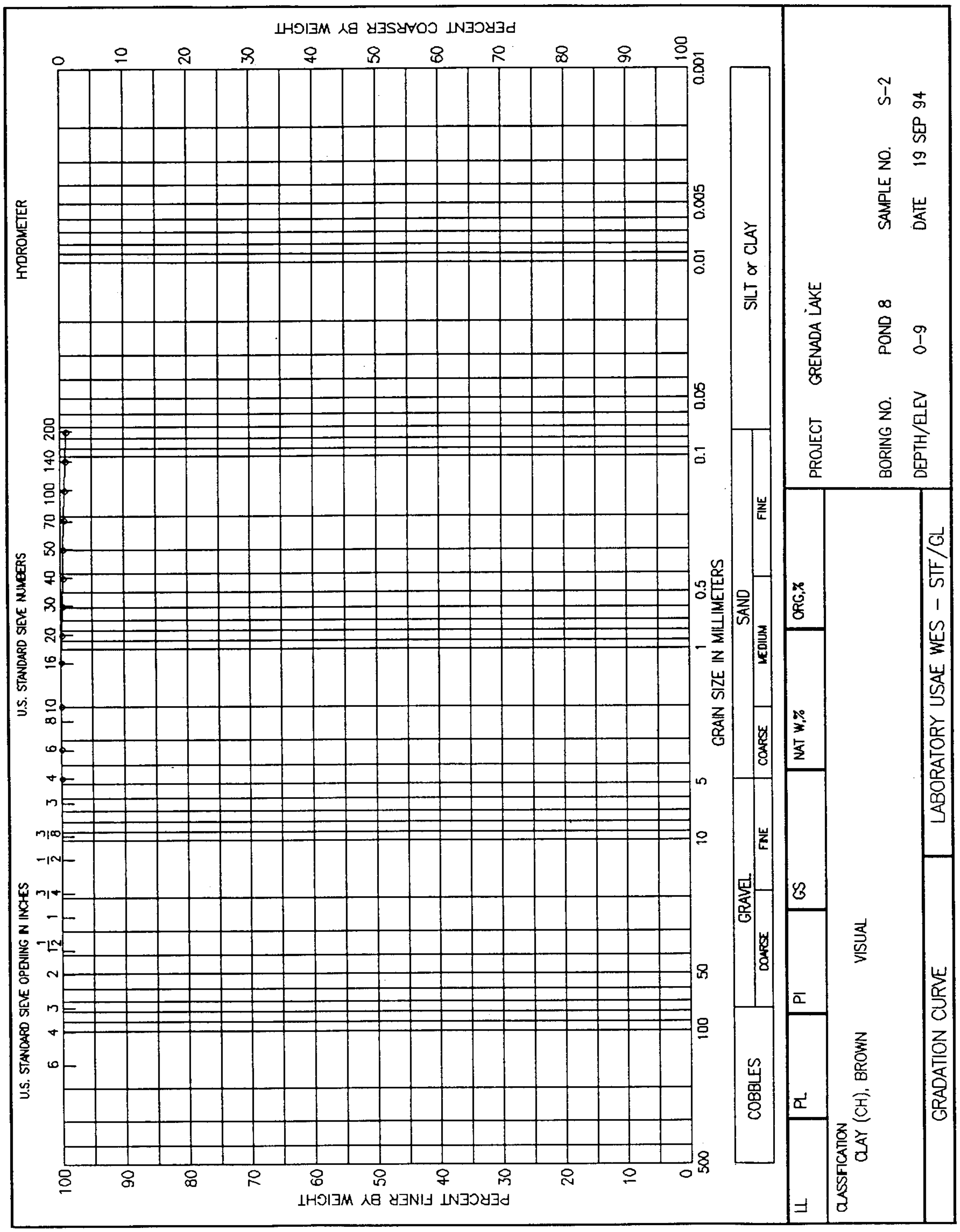
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 248
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 79.4 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.1	No 20	.850	99.9	.1
.2	No 30	.600	99.7	.3
.3	No 40	.425	99.6	.4
.3	No 50	.300	99.6	.4
.4	No 70	.212	99.5	.5
.5	No 100	.150	99.4	.6
.6	No 140	.106	99.2	.8
.7	No 200	.075	99.1	.9

PERCENT GRAVEL = .0
PERCENT SAND = .9
PERCENT FINES = 99.1

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 8
SAMPLE NO. S-2
DEPTH/ELEV 0-9
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 8 SAMPLE: S-3 DF: MD6194 .DAT
DEPTH: 0-3 DATE: 19 SEP 94

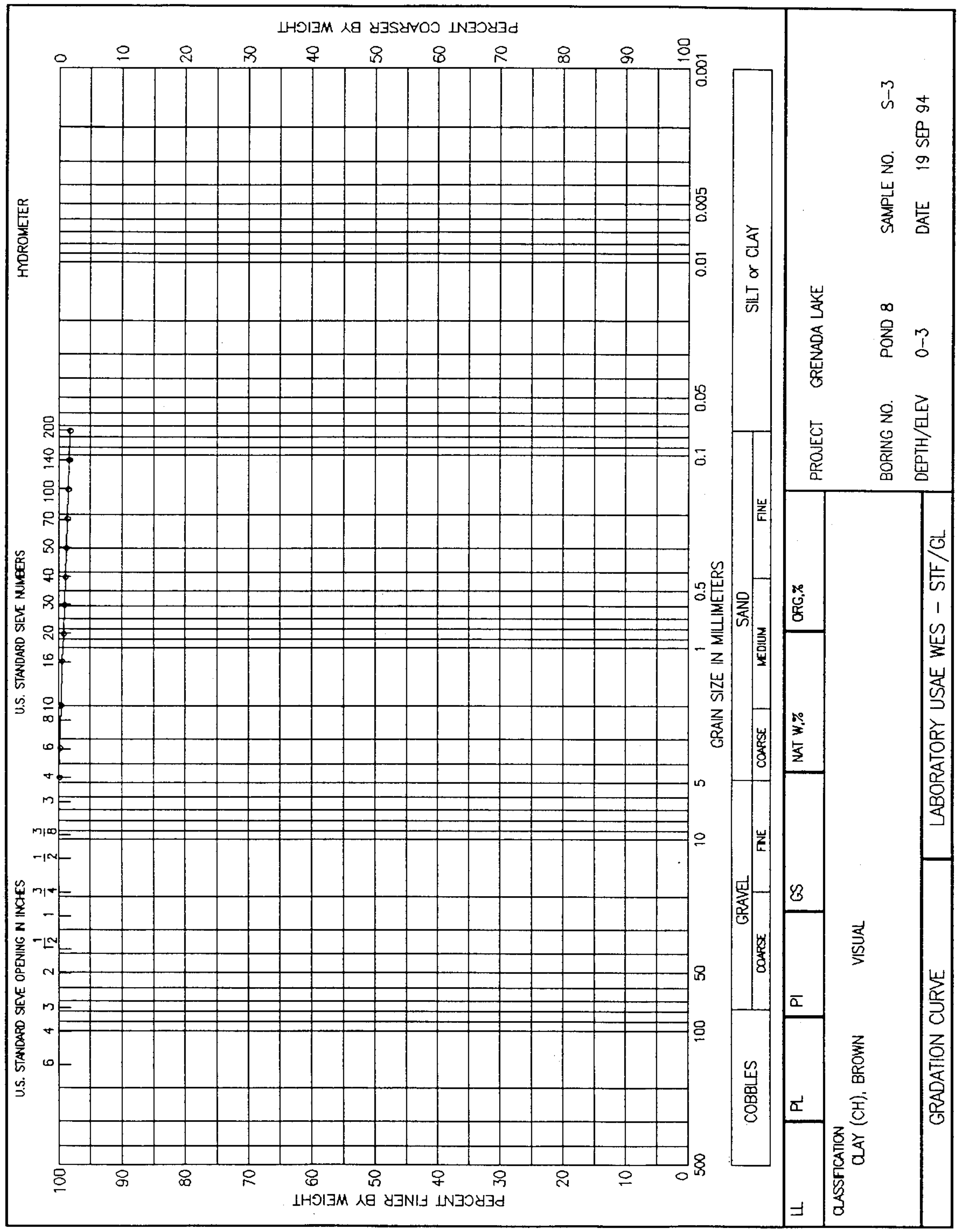
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 258
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 71.8 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.1	No 6	3.350	99.9	.1
.2	No 10	2.000	99.7	.3
.3	No 16	1.180	99.6	.4
.5	No 20	.850	99.3	.7
.6	No 30	.600	99.2	.8
.7	No 40	.425	99.0	1.0
.8	No 50	.300	98.9	1.1
.9	No 70	.212	98.7	1.3
1.0	No 100	.150	98.6	1.4
1.1	No 140	.106	98.5	1.5
1.2	No 200	.075	98.3	1.7

PERCENT GRAVEL = .0
PERCENT SAND = 1.7
PERCENT FINES = 98.3

EDE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 8
SAMPLE NO. S-3
DEPTH/ELEV 0-3
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 9 SAMPLE: S-1 DF: MD6194 .DAT
DEPTH: 0-33 DATE: 19 SEP 94

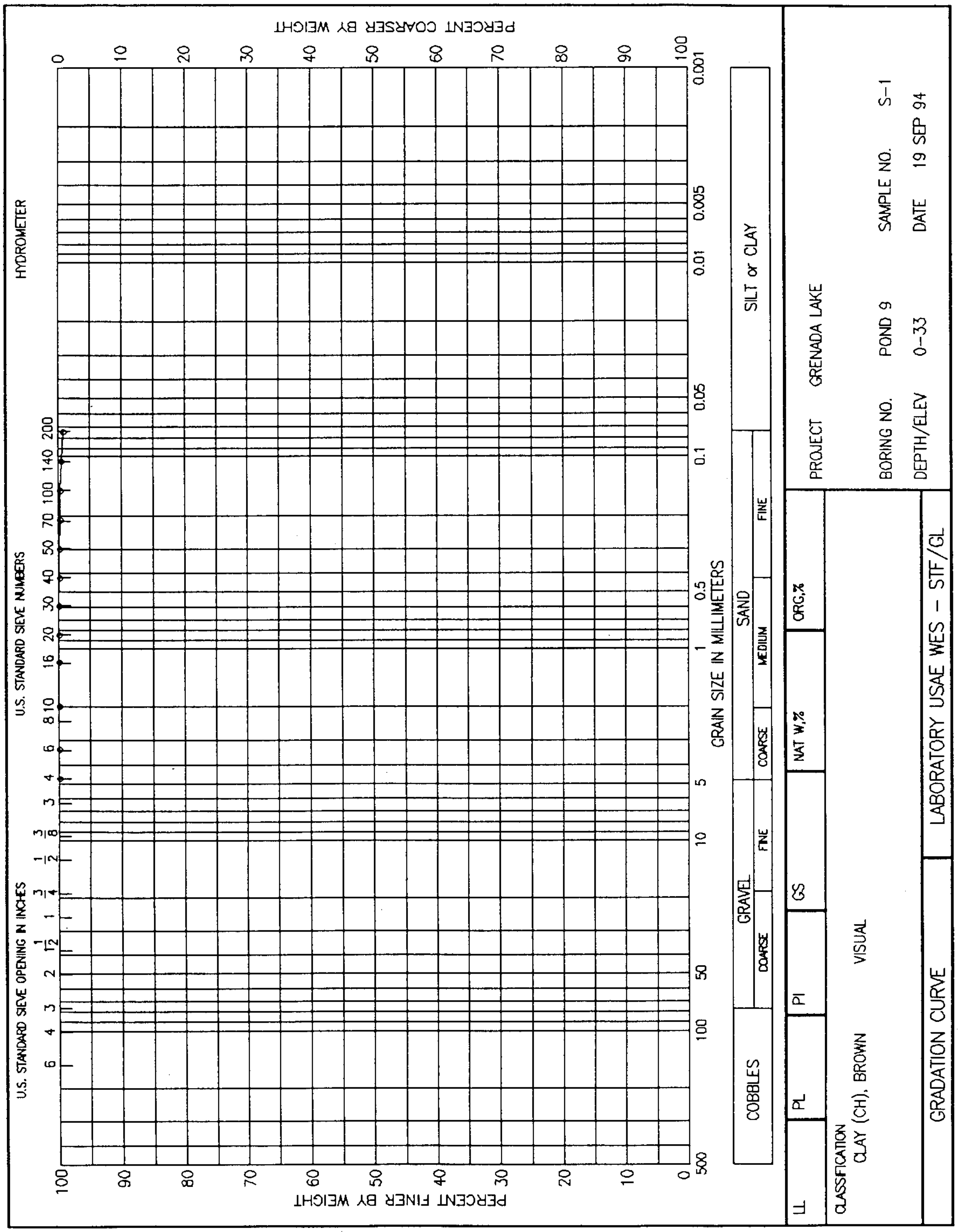
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 268
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 96.6 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.0	No 16	1.180	100.0	.0
.0	No 20	.850	100.0	.0
.0	No 30	.600	100.0	.0
.1	No 40	.425	99.9	.1
.1	No 50	.300	99.9	.1
.2	No 70	.212	99.8	.2
.2	No 100	.150	99.8	.2
.4	No 140	.106	99.6	.4
.7	No 200	.075	99.3	.7

PERCENT GRAVEL = .0
PERCENT SAND = .7
PERCENT FINES = 99.3

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 9
SAMPLE NO. S-1
DEPTH/ELEV 0-33
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 9 SAMPLE: S-2 DF: MD6194 .DAT
DEPTH: 0-15 DATE: 19 SEP 94

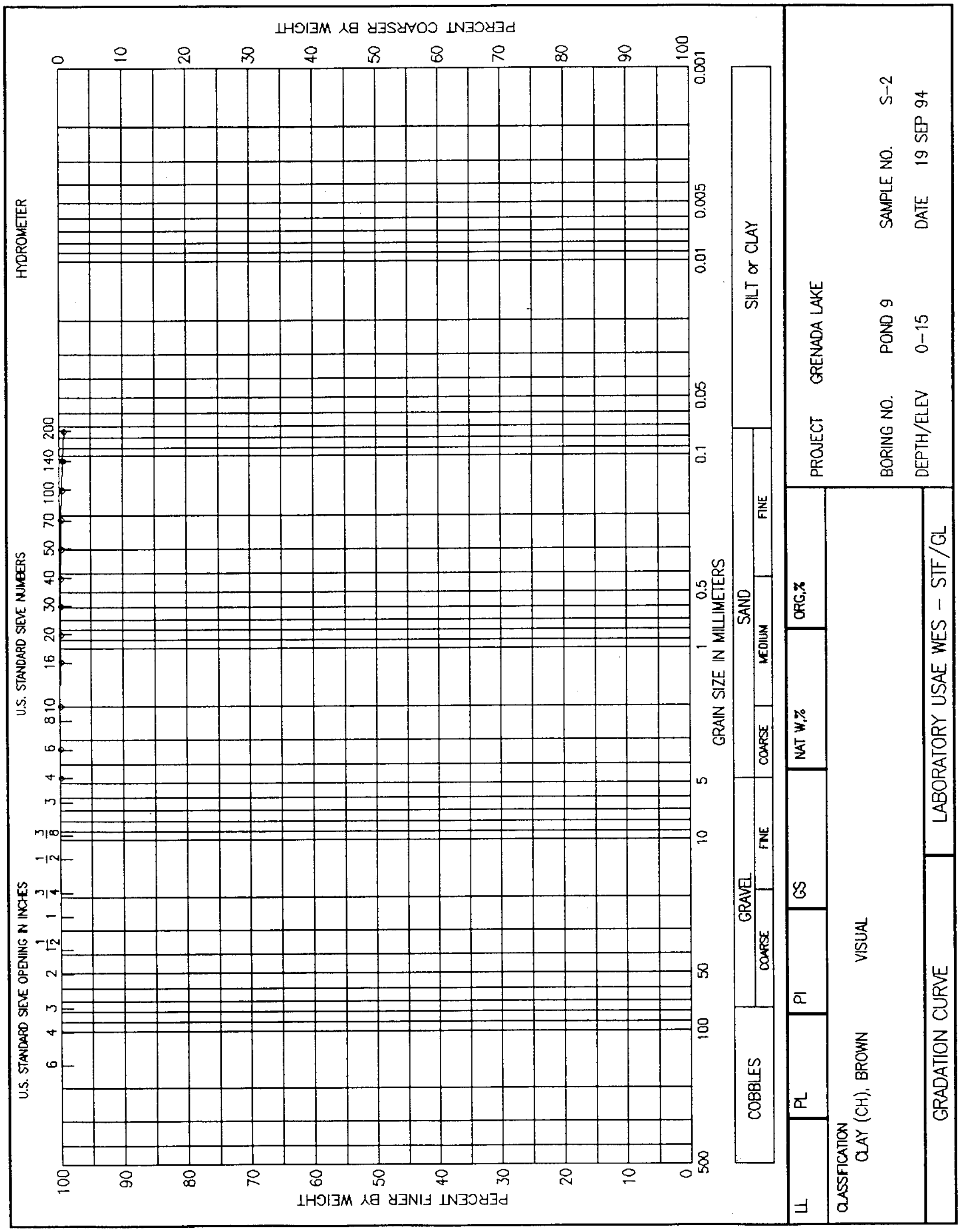
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 278
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 87.3 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.0	No 10	2.000	100.0	.0
.1	No 16	1.180	99.9	.1
.1	No 20	.850	99.9	.1
.1	No 30	.600	99.9	.1
.1	No 40	.425	99.9	.1
.2	No 50	.300	99.8	.2
.2	No 70	.212	99.8	.2
.3	No 100	.150	99.7	.3
.4	No 140	.106	99.5	.5
.6	No 200	.075	99.3	.7

PERCENT GRAVEL = .0
PERCENT SAND = .7
PERCENT FINES = 99.3

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1 1/2 1 3/4 1/2 3/8 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
PROJECT GRENADA LAKE
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
BORING NO. POND 9
SAMPLE NO. S-2
DEPTH/ELEV 0-15
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

SIEVE ANALYSIS

PROJECT: GRENADA LAKE

BORING: POND 9 SAMPLE: S-3 DF: MD6194 .DAT
DEPTH: 0-12 DATE: 19 SEP 94

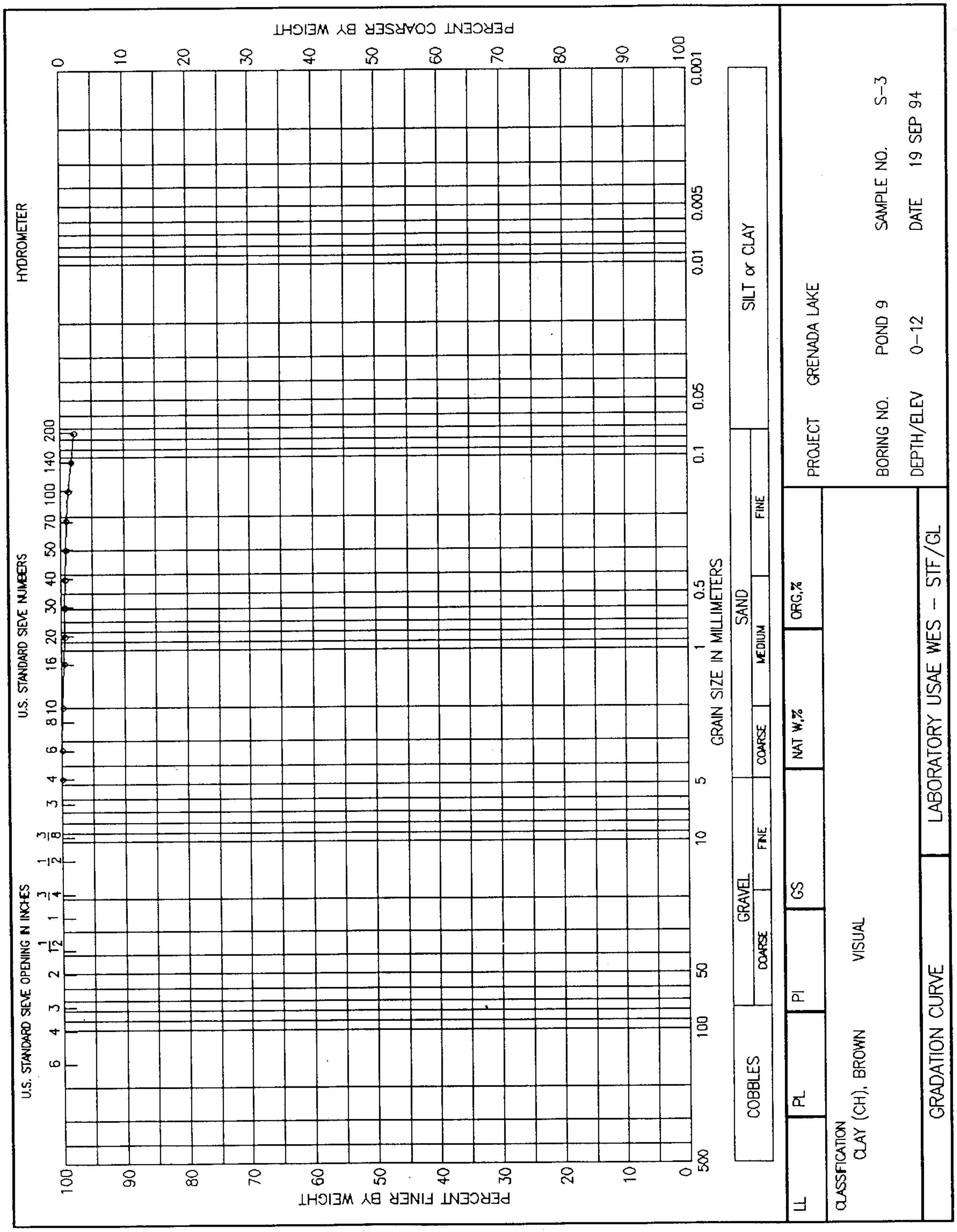
NO-LIMITS-RAN GS: .00 WC: .00
CLASSIFICATION: 288
CLAY (CH), BROWN VISUAL

TOTAL WEIGHT OF SAMPLE: .0 gms.
PARTIAL WEIGHT AFTER SPLIT: 84.5 gms.

WEIGHTS gm.	SIEVE SIZE or NUMBER	OPENING mm	PERCENT FINER	PERCENT COARSER
.0	No 4	4.750	100.0	.0
.0	No 6	3.350	100.0	.0
.1	No 10	2.000	99.9	.1
.3	No 16	1.180	99.6	.4
.4	No 20	.850	99.5	.5
.4	No 30	.600	99.5	.5
.5	No 40	.425	99.4	.6
.6	No 50	.300	99.3	.7
.7	No 70	.212	99.2	.8
1.0	No 100	.150	98.8	1.2
1.4	No 140	.106	98.3	1.7
1.8	No 200	.075	97.9	2.1

PERCENT GRAVEL = .0
PERCENT SAND = 2.1
PERCENT FINES = 97.9

EDE


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
ORG,%
CLASSIFICATION
CLAY (CH), BROWN
VISUAL
PROJECT GRENADA LAKE
BORING NO. POND 9
SAMPLE NO. S-3
DEPTH/ELEV 0-12
DATE 19 SEP 94
GRADATION CURVE
LABORATORY USAE WES - STF/GL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

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Final report

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Characteristics and Long-Term Sedimentation Patterns of Wetlands Constructed in the Fluctuation Zone of Grenada Lake, Mississippi

5. FUNDING NUMBERS
Work Unit #32766

6. AUTHOR(S)
Charles W. Downer, Ron DeLaune, J. Andy Nyman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; Laboratory for Soils and Sediments, Center for Wetland Resources, Louisiana State University, Baton Rouge, LA 70803; Department of Biology, University of Southwestern Louisiana, P.O. Box 42451, Lafayette, LA 70504-2451

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12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Wetlands were constructed in the Grenada Lake fluctuation zone during the late 1950s shortly after construction of the reservoir. These wetlands were planted with grain to attract waterfowl for hunting and were termed shooting ponds. After a change in the rule curve of the reservoir caused more frequent flooding of the shooting ponds, planting and water-level manipulation of the ponds were discontinued. Over the years, the shooting ponds became valuable wetland habitat with natural vegetation. These wetlands were chosen as a demonstration site to study long-term sedimentation patterns in wetlands constructed in the fluctuation zone of reservoirs. Nineteen sediment cores were collected from eight different wetland areas. Sediment accumulation in the wetlands was determined by ^{137}Cs analysis of the cores. The cores were also sampled for bulk density, percent moisture, organic content, and grain size. Analysis showed that the wetlands were accreting 0.49 cm/year of sediments and accumulating 4.35 kg/m^2/year of sediments. The average bulk density of cores was 1.00 g/cm^3. Average mineral content was 94 percent. Sediments were 98.2-percent fines by weight. No distinct patterns in sedimentation among wetlands was apparent. It is thought that micro differences between the wetlands play a large role in determining sedimentation at this site.

14. SUBJECT TERMS
Construction
Reservoir
Sediment
Sedimentation
Wetlands

15. NUMBER OF PAGES
116

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		